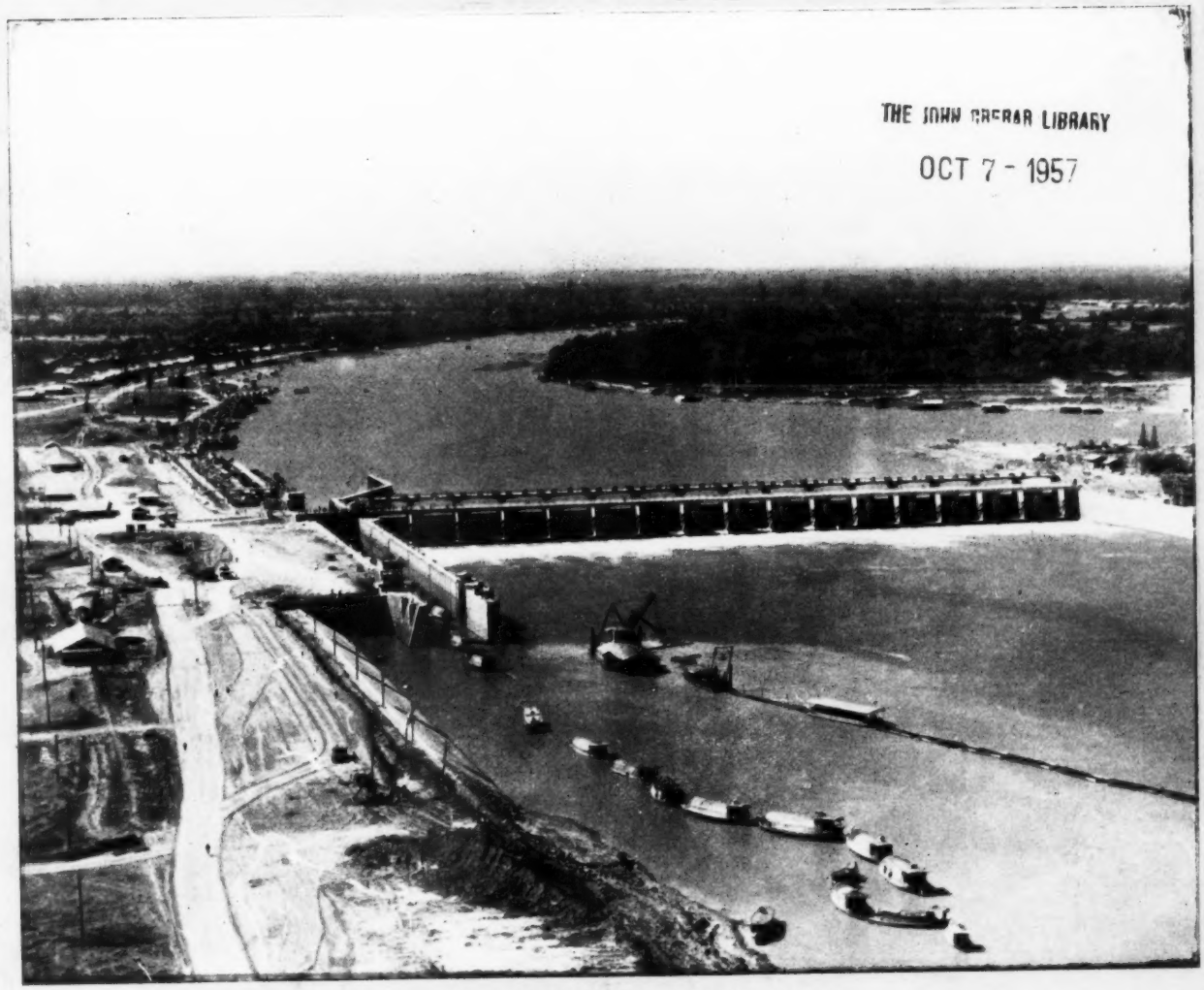
T2
163

INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

VOL. VII. NO. 5 MAY 1957 RUPEES TWO

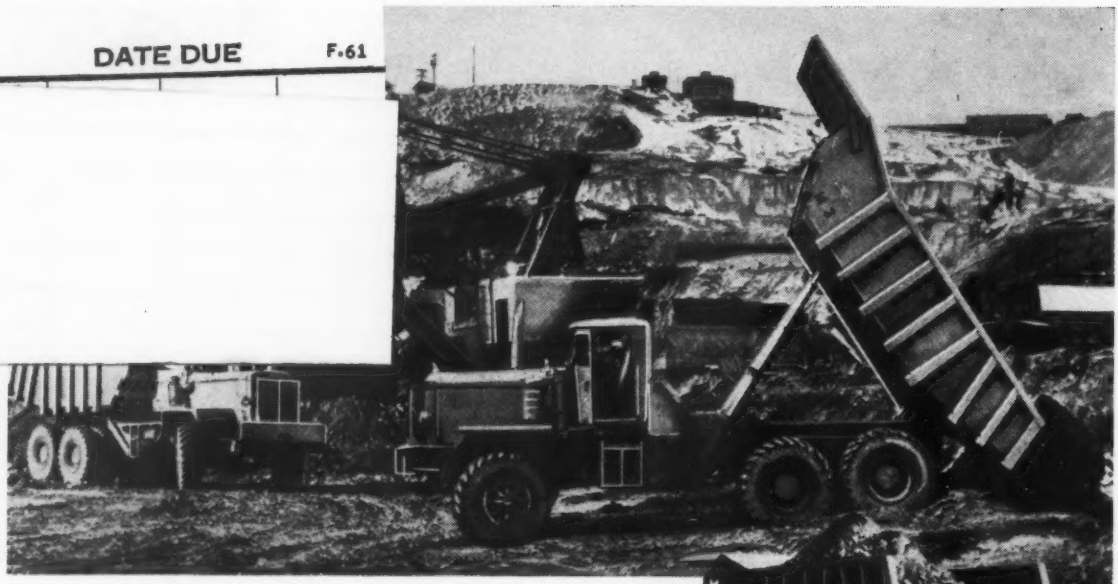


THE JOHN CRERAR LIBRARY
OCT 7 - 1957

THE CHAINAT DAM, THAILAND

V 7 5 MAY 57 UM

DATE DUE F.61



Mack first name in REAR DUMPERS

When it comes to hauling earth, rock or any heavy materials, construction engineers know there's nothing like Macks. They recognise Macks as the ONE machine offering a combination of stamina, rugged construction, operating economy and low maintenance costs; and that means the most economical hauling on the toughest jobs, over the roughest terrains.

Here are some of the projects to which Mack equipment has been supplied:

- Damodar Valley Project
- Hirakud Project
- Rihand Dam
  (20 Mack cement carriers supplied to the Hinusthan Constrction Company)
- Tata Iron & Steel Co's expansion Project
- Nagarjunasagar Project

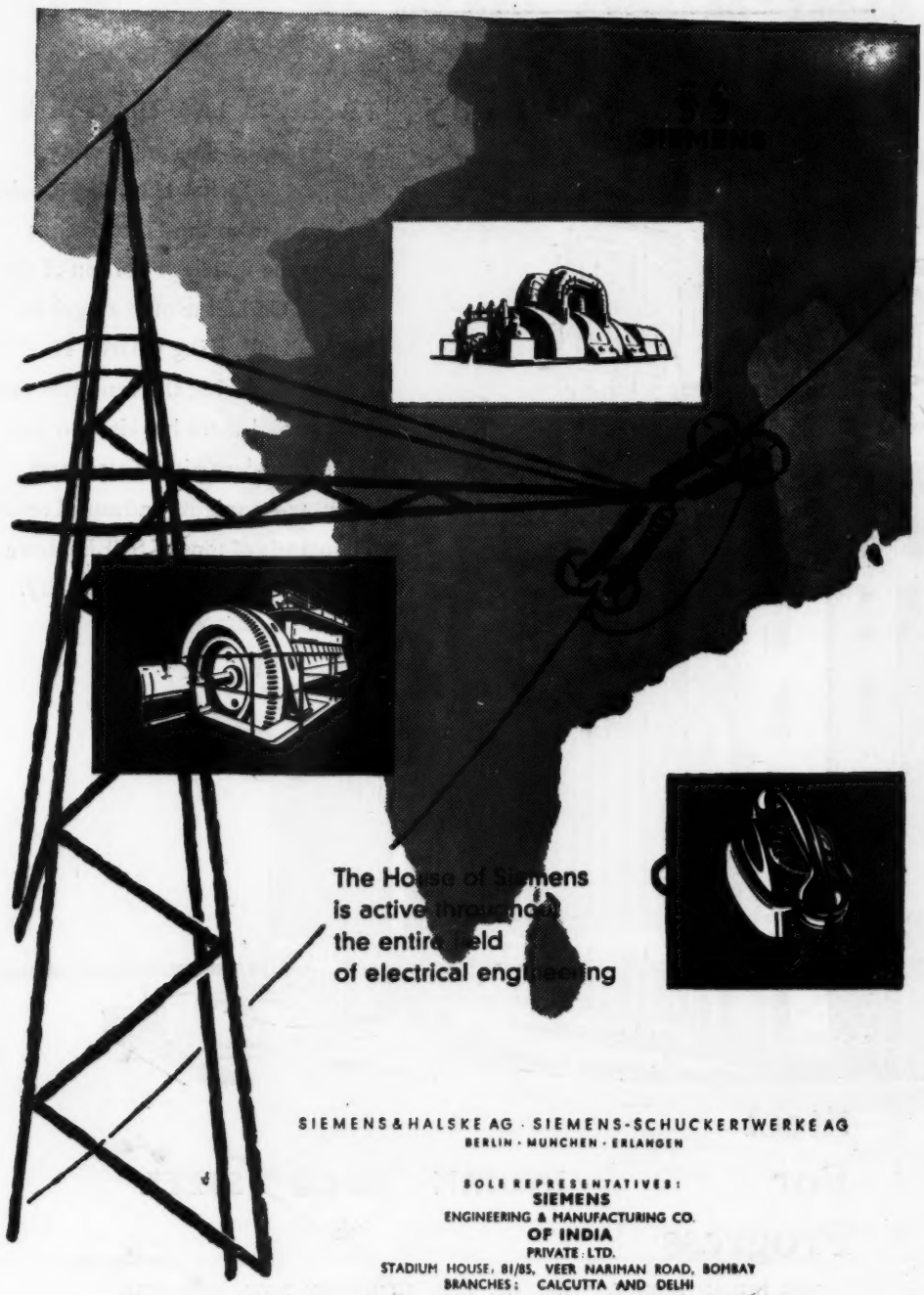
Remember, Macks in India are backed by Voltas' unrivalled service and spare parts organisation.

VOLTAS LIMITED
Construction Equipment Dept.,

VOLTAS

Bombay • Calcutta • Madras • New Delhi • Bangalore • Cochin • Lucknow
Ahmedabad • Secunderabad.

VOL. 57-10



SIEMENS & HALSKE AG · SIEMENS-SCHUCKERTWERKE AG
BERLIN · MUNCHEN · ERLANGEN

SOLE REPRESENTATIVES:
SIEMENS
ENGINEERING & MANUFACTURING CO.
OF INDIA
PRIVATE LTD.
STADIUM HOUSE, 81/85, VEER NARIMAN ROAD, BOMBAY
BRANCHES: CALCUTTA AND DELHI

" Where now the city stands,
there was once naught but the city's site." OVID

Bombay

February 18, 1665. Only a small island of mud-flats and fishing villages, was what Humphry Cooke took over from the Portugese, as part of the marriage portion of the Infanta Catherine of Portugal for her husband, King Charles II of England. During the centuries that have passed there has risen in that place a modern city of steel and concrete—a mighty industrial centre. Thousands of tons of STEEL have gone into the making of this city.

Bombay Street scene —18th Century

Bombay Govt. Secretariat

Steel For Progress

INDIAN IISCO STEEL

THE INDIAN IRON & STEEL CO. LTD. 12 MISSION ROW, CALCUTTA

IIC 58

You need the Muir-Hill Reqd. 2-WL

1 CU. YD.

HYDRAULIC LOADER

DIGS The 2-WL is of tremendously strong construction and will dig, carry and load the toughest materials. A range of 6 buckets operated with controlled and automatic roll back from ¾ to 3 cu. yds. nominal capacity is available to suit the material being handled.

CARRIES The Muir-Hill 2-WL Loader has a patented safety suspension system which gives it the stability to travel at speed over rough ground with a full bucket. The 2-WL is easy to operate and very high loading rates are achieved.

LOADS The 2-WL will load all types of vehicles, hoppers, concrete batching plant and other elevated structures. The model has a maximum upward reach of 10′ 11″ and a maximum forward reach of 5′ 2¾″.

BUILT BY BOYDELL

E. BOYDELL & CO. LTD., ALLIANCE WORKS, OLD TRAFFORD, MANCHESTER 16, ENGLAND

DISTRIBUTORS IN INDIA

Messrs. McLeod & Co. Ltd., McLeod House, P.O.B. 78, Postal Zone No. 1, Calcutta.

Territories :

Uttar Pradesh, Bihar, Assam, West Bengal, Orissa, Southern Andhra Pradesh, Southern Mysore, Madras, Kerela.

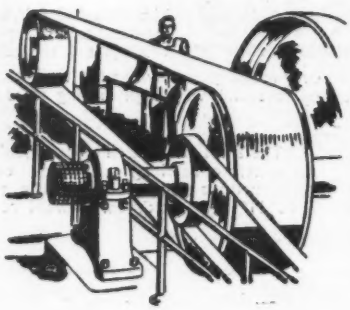
Messrs. Killick, Nixon & Co. Private Ltd., P.O.B. 109, Killick House, Home Street, Bombay.

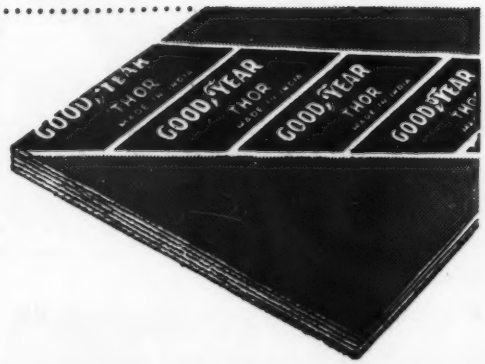
Territories :

Punjab, Himachal Pradesh, Rajasthan, Madhya Pradesh, Bombay, Northern Mysore, Northern Andhra Pradesh.

dm EB 714

THOR HEAVY DUTY TRANSMISSION BELTING





BETTER BELTS
FOR EVERY DRIVE BY

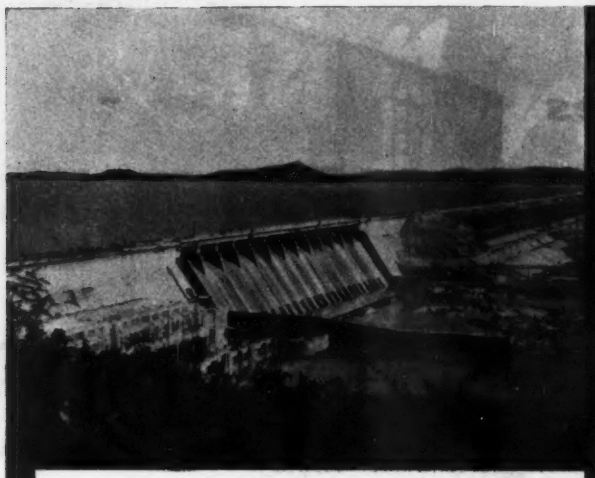
No matter what your belting needs, there's a Goodyear belt that will do the job better at lowest cost. Goodyear's line of belts is *complete* and covers every possible use. Let us check your installation—we'll recommend the *right* Goodyear belt for your job.

INDUSTRIAL PRODUCTS DEPARTMENT

GOODYEAR

THE GREATEST NAME IN RUBBER

PSIP 1



HIRAKUD DAM POWER PROJECT

The inauguration of the Hirakud Dam Power Project by Pandit Nehru, Prime Minister of India, opens a new phase in the economic life of the country. Harnessing the Mahanadi river, the Hirakud Dam Project will bring power to the millions. **A. E. I.** are proud of the part they have played in the supply and erection of electrical equipment.

LIST OF EQUIPMENTS SUPPLIED TO THE HIRAKUD DAM PROJECT

By **A. E. I.**

Two 42 MVA, 11/132 kV transformers.
Two 27 MVA, 11/132 kV transformers.
Two 12.5MVA 132/66 kV transformers.
Two 2000 kVA 66/11 kV transformers.
Two 600 kVA 11 kV/420 volts transformers.
Four 200 kVA 11 kV/420 volts transformers.
14 Nos. 132 kV 2500 MVA oil circuit breakers.
6 Nos. 66 kV 500 MVA oil circuit breakers.
34 Nos. 132 kV 400 amps isolating switches.
16 Nos. 66 kV 400 amps isolating switches.
36 Nos. 132 kV single phase lightning arresters.
24 Nos. 66 kV single phase lightning arresters.
One 7 panel 11 kV 75 MVA switchboard.
14 panel 132 kV control & relay boards with 4 control desks and synchronising equipment.
6 panel 66 kV control and relay boards.
4 Nos. neutral earthing cubicles.
4 Nos. surge protection cubicles.
Four 420 volts unit auxiliary switchboards.
One 420 volts station service switchboard.
Two 420 volts switchyard auxiliary switchboards.
One 230 volts 353 amp-hour D. C. battery and battery control board.
Control cables.
Four Nos. oil filtration plants.

ASSOCIATED ELECTRICAL INDUSTRIES (INDIA) PRIVATE LTD.

Head Office: Crown House, 6 Mission Row, Calcutta.

Branches at:

BOMBAY NEW DELHI MADRAS BANGALORE COIMBATORE NAGPUR

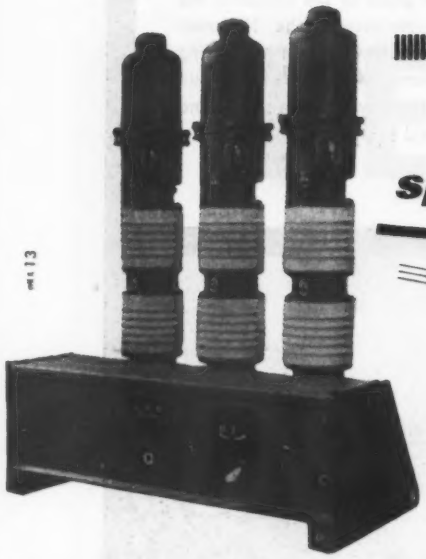
Associated Companies

ASSOCIATED ELECTRICAL INDUSTRIES MFG. CO. PRIVATE LTD.
BIRLEC LTD.
THE BRITISH THOMSON-HOUSTON CO. LTD.
FERGUSON PAILIN LTD.
THE HOTPOINT ELECTRIC APPLIANCE CO. LTD. (Coldrator and Premier Divisions)
METROPOLITAN-VICKERS ELECTRICAL CO. LTD.
METROPOLITAN-VICKERS GRS. LTD.
NEWTON VICTOR LTD.
SIEMENS EDISON SWAN (EXPORT) LTD.
SUNVIC CONTROLS LTD.

AIC-169A

New series of medium voltages

circuit breakers



spring operation

mt type

Scarpa & Magnano

Savona - Italy

ON GOVT. RATE CONTRACT

OSLER

INDIA'S QUALITY LAMP

Manufactured by:

THE OSLER ELECTRIC LAMP MFG. CO., LTD.

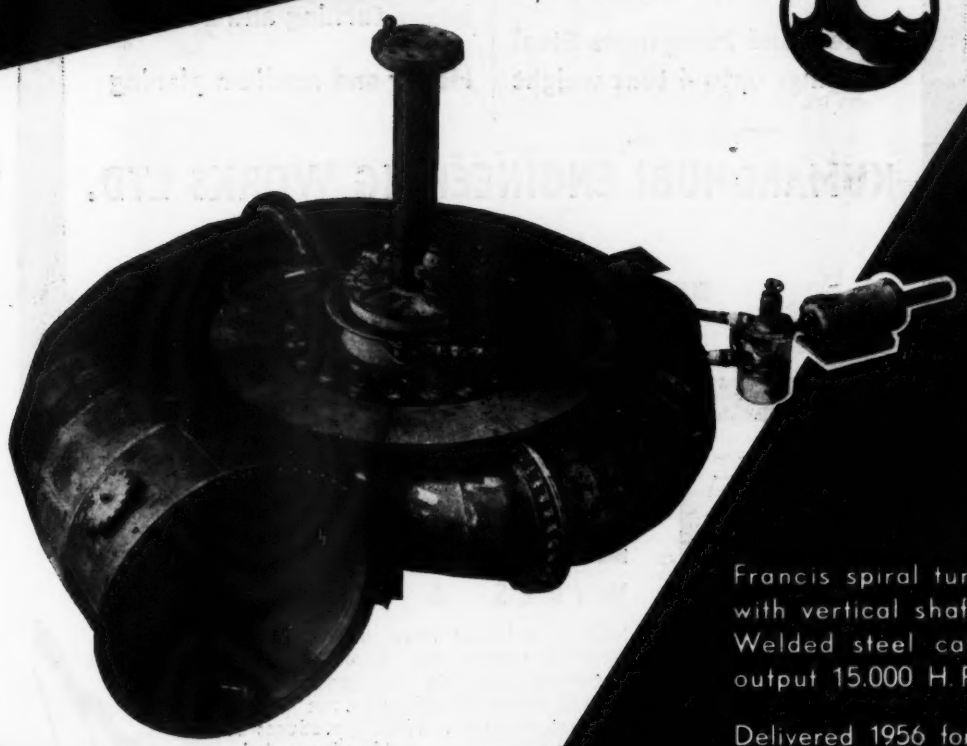
39-43, Nesbit Road, Bombay-10

Sole Distributors:

F. & C. OSLER (INDIA) LTD.

Calcutta . Bombay . New Delhi . Madras . Kanpur . Gauhati . Jullundur

Design Supply Erection



Francis spiral turbine with vertical shaft. Welded steel casing, output 15.000 H. P.

Delivered 1956 for the Ottenstein power station, Austria

of complete

power station equipment

J.M.VOITH **AUSTRIA**

St. Poelten, P.O.B. 168 Teletype 01 2148 Telegrams : Voithwerk St. Poelten

Steel Structures
Mechanical Plant
Ropeways & Cableways
Steel and Manganese Steel castings upto 4 tons weight

Accurate milling and hobbing of gears
Light, medium and heavy turning and boring
Heavy and medium planing

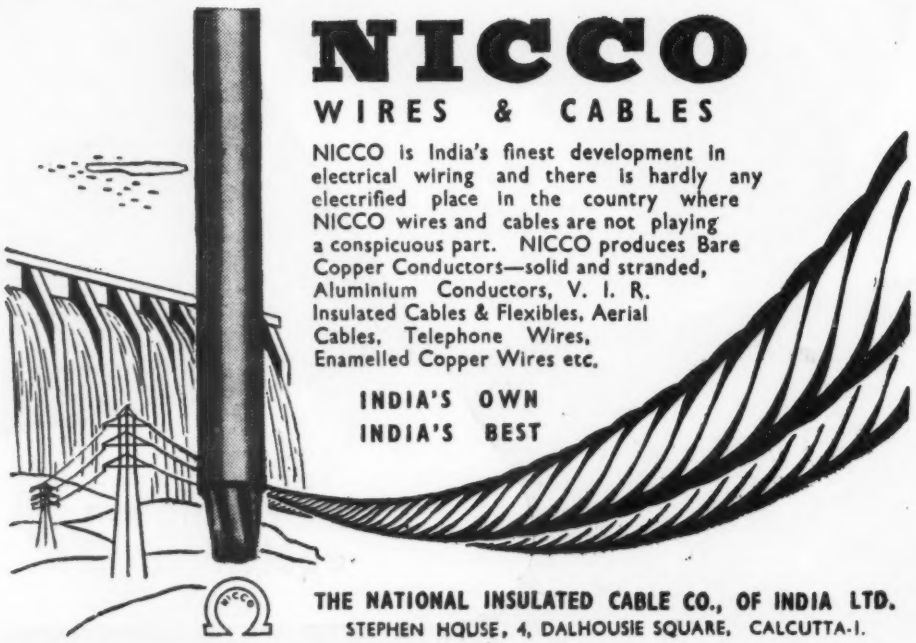
KUMARDHUBI ENGINEERING WORKS LTD.

Managing Agents :
BIRD & CO., (PRIVATE) LTD.
Chartered Bank Buildings, Calcutta-1

B 236

NICCO
WIRES & CABLES

NICCO is India's finest development in electrical wiring and there is hardly any electrified place in the country where NICCO wires and cables are not playing a conspicuous part. NICCO produces Bare Copper Conductors—solid and stranded, Aluminium Conductors, V. I. R. Insulated Cables & Flexibles, Aerial Cables, Telephone Wires, Enamelled Copper Wires etc.



INDIA'S OWN
INDIA'S BEST

THE NATIONAL INSULATED CABLE CO., OF INDIA LTD.
STEPHEN HOUSE, 4, DALHOUSIE SQUARE, CALCUTTA-1.

FERRANTI
TRANSFORMERS
F
FERRANTI
INDIA Five 3-phase transformers, three 20 MVA, 132/33-66 kV and two 10 MVA, 132/33 kV, have been supplied for the Damodar Valley Power Scheme.
NEW ZEALAND Twenty-six 220 kV single-phase transformers have been ordered by the State Hydro-Electric Department of New Zealand. Thirteen have already been supplied.
U.S.A. Of nine 33.3 MVA, 230 kV single-phase transformers being supplied to the U.S. Army Corps of Engineers for the Garrison Dam Project, N. Dakota, three have been shipped.
CANADA Four 300 kV, 71 MVA and three 275 kV,
transformers have been supplied to the Aluminium
of Canada for the Alcan Project at
FERRANTI TRANSFORMERS FAMOUS THROUGHOUT THE WORLD

FERRANTI LTD. HOLLINWOOD · LANCASHIRE · ENGLAND

Sole Agents in India: **BRITISH INSULATED CALLENDER'S CABLES LIMITED**
Esplanade House, Waudby Road, Fort, Bombay 1 Post Box 111

Branches at: AHMEDABAD · AMBALA · BANGALORE · CALCUTTA · COIMBATORE
KANPUR · MADRAS · NAGPUR · NEW DELHI · SECUNDERABAD (Deccan)

increased power with compression cables

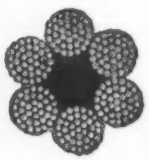
To carry power loads of voltages above 66kV and up to 275kV, efficiently and economically, Enfields have evolved Compression Cables. They consist of normal paper-insulated, lead-sheathed cables of non-circular section surrounded by a gas pressure of about 200 pounds per square inch. Compression Cables are available in two different forms: the pipe-line type and the self-contained type.

AN Enfield PRODUCT

Paper Insulated Cables.
Rubber Insulated Cables.
Non-Bleeding Cables.
Signalling & Telephone Cables.
Machine & Transformer Winding Wires.
Joint Boxes & Feeder Pillars.
Grid Suspension Wiring System

PLX 388

Agents in India
PHILIPS INDIA PRIVATE LTD.
7, Justice Chandra Madhab Road, Calcutta 20. *Branches :* Bombay - Delhi - Madras - Patna - Kanpur - Lucknow - Bangalore.



STEEL WIRE ROPES

Manufactured by :

GLAHOLM & ROBSON LTD.

Messrs. Glaholm & Robson are manufacturers of the highest quality steel wire ropes for Mining, Engineering and Shipping purposes. All ropes are made throughout entirely from British Steel and are subject to the most severe tests before leaving the manufacturer's works.

Messrs. Lloyds' certificates can be furnished if desired.

Please write for information and price to the Agents :

JESSOP & Co LTD
ENGINEERS

63, NETAJI SUBHAS ROAD, -- CALCUTTA - 1.

Gradall

THE MULTI-PURPOSE EXCAVATOR

No wonder Gradall is the ideal machine of every contractor—it handles so many different jobs that a contractor can keep it busy from start to finish on any contract. With its quickly inter-changeable attachments and smooth arm-action accuracy, it does the work of 8 different single-purpose machines.

Does all these
. . . . and many more !

- Cleaning open hearth furnaces.
- Hand finishing and clean-up.
- Excavating and loading.
- Trenching and backfilling.
- Snow and ice removal.
- Ditch digging and cleaning.
- Grading and sloping.
- Materials handling.
- Ripping and loading pavement.
- Placing culverts. Tanks, curbs, etc.
- Working under bridges and around other structures.

Yes, a Gradall can do them all. Its tremendous power will dig in rock or rip reinforced concrete. Yet the same machine can be used for such difficult and delicate operations as working inside a building or a ship's hold.

SAVES MONEY TOO. A Gradall's easy manoeuverability provides more *working* hours in each day. And that is not all — on the job you can change an attachment in 4½ minutes, giving you a "new" machine, with no delay in waiting for other equipment. A Gradall saves you time and labour—*which means more money for you.*

Rubber tyred or crawler mounted

Whatever the job- **Gradall** *will handle it!*

Sole distributors in India

BLACKWOOD HODGE

BLACKWOOD HODGE (INDIA) PRIVATE LTD.

CALCUTTA • MADRAS • DELHI • BOMBAY

Associated Companies Branches Works and Agencies throughout the world

G/P/1

FOR LONG LIFE
AND SERVICE
IN THE TROPICS

Specify

PARAMITE

CABLES

MADE IN INDIA BY

THE INDIAN CABLE COMPANY LTD

9, HARE STREET, P. O. BOX 514, CALCUTTA

REPRESENTATIVES IN INDIA FOR

BRITISH INSULATED CALLENDER'S CABLES LTD

BRANCHES :

AHMEDABAD, AMBALA, BANGALORE, BOMBAY, COIMBATORE, JAMSHEDPUR, KANPUR, MADRAS, NAGPUR, NEW DELHI AND SECUNDERABAD

IC 5

VTA
ESTABLISHED 1874
Modern
AERIAL ROPEWAYS
for materials & passengers
Further details also from :
TRADE REPRESENTATION
of the
GERMAN DEMOCRATIC
REPUBLIC
Branch Office : Calcutta
P-17, Mission Row Extension
VEB SCHWERMASCHINENBAU
VERLADE- u. TRANSPORTANLAGEN
vorm. BLEICHERT Leipzig
TECHNICAL REPRESENTATIVES C.A. WILLNER & CO. PB 59 BANGALORE 1
DW-139

WATER...

...Key to INDIA'S Future

Huwood Conveyors are playing their part in the construction of the many dams now being built across the Indian rivers — dams which have the purpose of combining irrigation with the production of cheap electric power. Dam construction is testing work for the conveyors employed .. contractors must be sure of obtaining equipment which is both reliable and exactly adapted to their needs.

Hugh Wood & Co., Ltd.,

Head Office and Factories
GATESHEAD - ON - TYNE, 11
Telegrams: Huwood, Gateshead Telephone: Low Fell 76083 (5 lines)

Industrial and Export Office
DASHWOOD HOUSE, 69, OLD BROAD STREET, LONDON, E.C.2.
Telegrams: Huwood, Ave, London Telephone: London Wall 6611-2-3

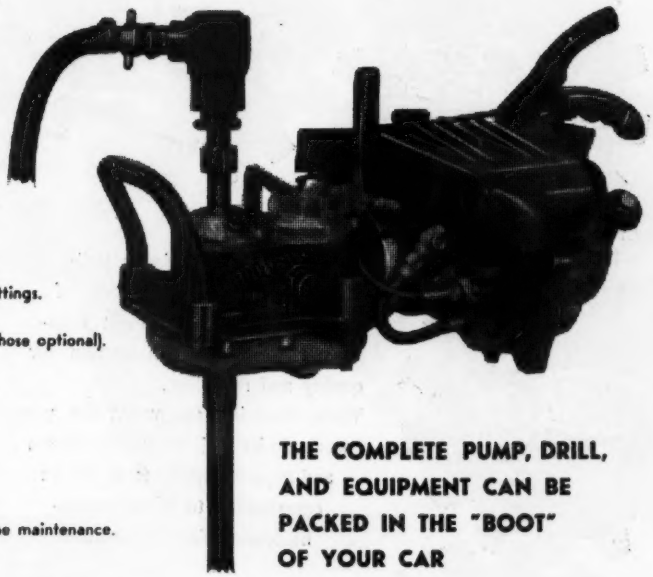
An Announcement to All Civil Engineering Contractors and Construction Projects.

ONE MAN OPERATED DIAMOND DRILL RIG FOR FOUNDATION INVESTIGATION

MINDRILL "MINOR"

The Mighty Midget

COMPLETE PORTABLE DIAMOND DRILL FOR PROSPECTING, BLAST HOLES, HYDRO - PROJECTS, CONCRETE TESTING, MINERAL SAMPLING, TOE HOLES & POPPING



5 h.p. air-cooled petrol motor.
Petrol-driven water pump and fittings.
3-ft. Suction hose.
20-ft. Delivery hose (additional hose optional).
Water swivel.
5-ft. Double tube core barrel.
1-ft. Starting barrel.
50-ft. Drill rods.
1 Diamond set reamer shell.
2 Diamond set Core bits.
2 18-in. Mindrill wrenches.
Complete set of tools for engine maintenance.
Operating manual.
Hand lever feed bar or
Foot-operated wire pull down for hard drilling conditions.

THE COMPLETE PUMP, DRILL, AND EQUIPMENT CAN BE PACKED IN THE "BOOT" OF YOUR CAR

A number already in service in India

A wide range of other larger models of "MINDRILL" drills is also available just to suit your requirements.

Inexpensive in initial as well as running cost

AVAILABLE EX-STOCK

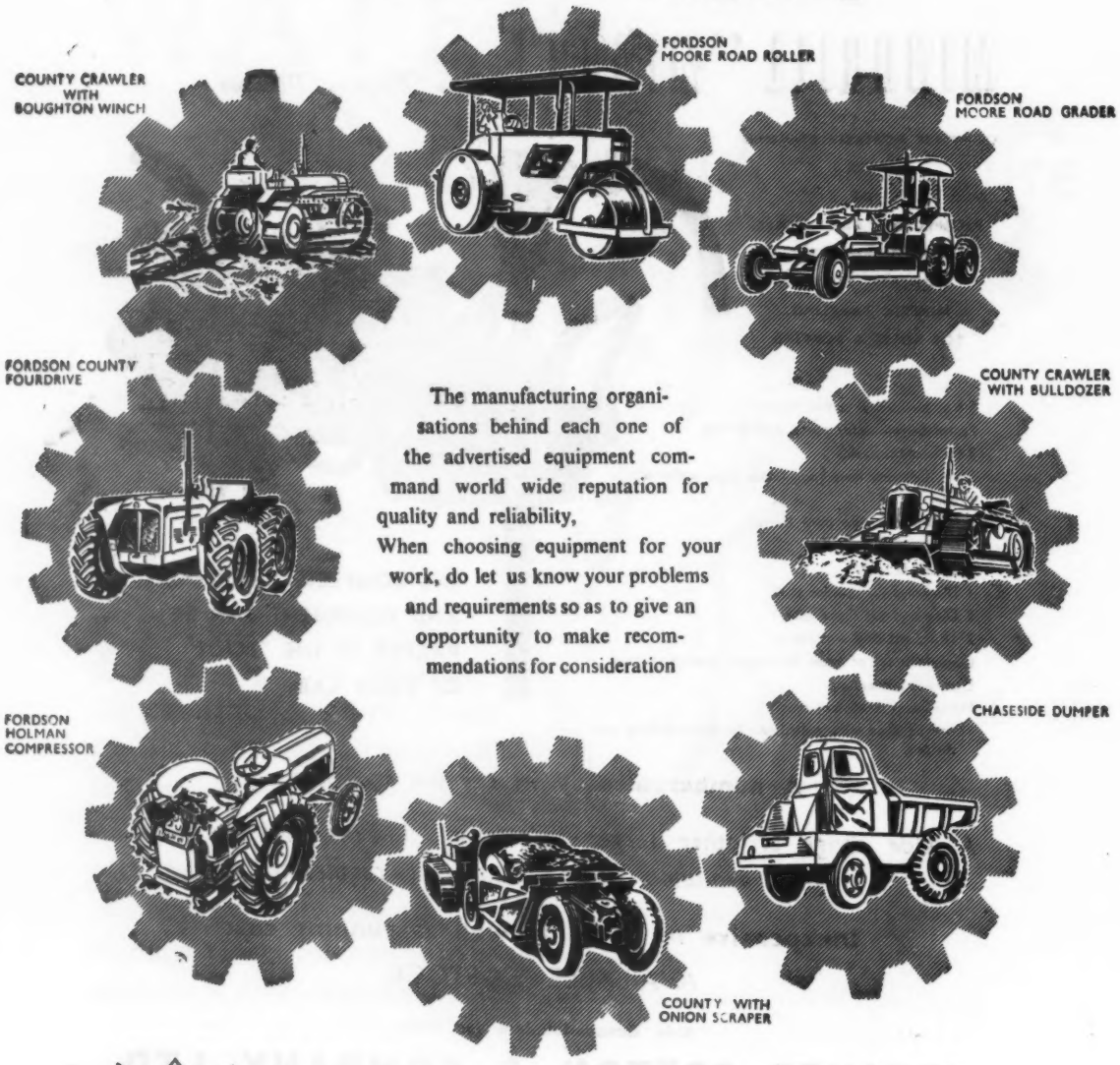
Sole Concessionaires for India:

GREAVES COTTON & COMPANY LTD.

BOMBAY • AHMEDABAD • BANGALORE • CALCUTTA • COIMBATORE • KANPUR
MADRAS • NEW DELHI

CALCUTTA BRANCH: Ralli House, 16, Hare Street, Post Box 702, CALCUTTA.

Famous Names Geared To India's Prosperity



The manufacturing organisations behind each one of the advertised equipment command world wide reputation for quality and reliability,
When choosing equipment for your work, do let us know your problems and requirements so as to give an opportunity to make recommendations for consideration

U.P.C.C
EVERYTHING FOR THE FARM

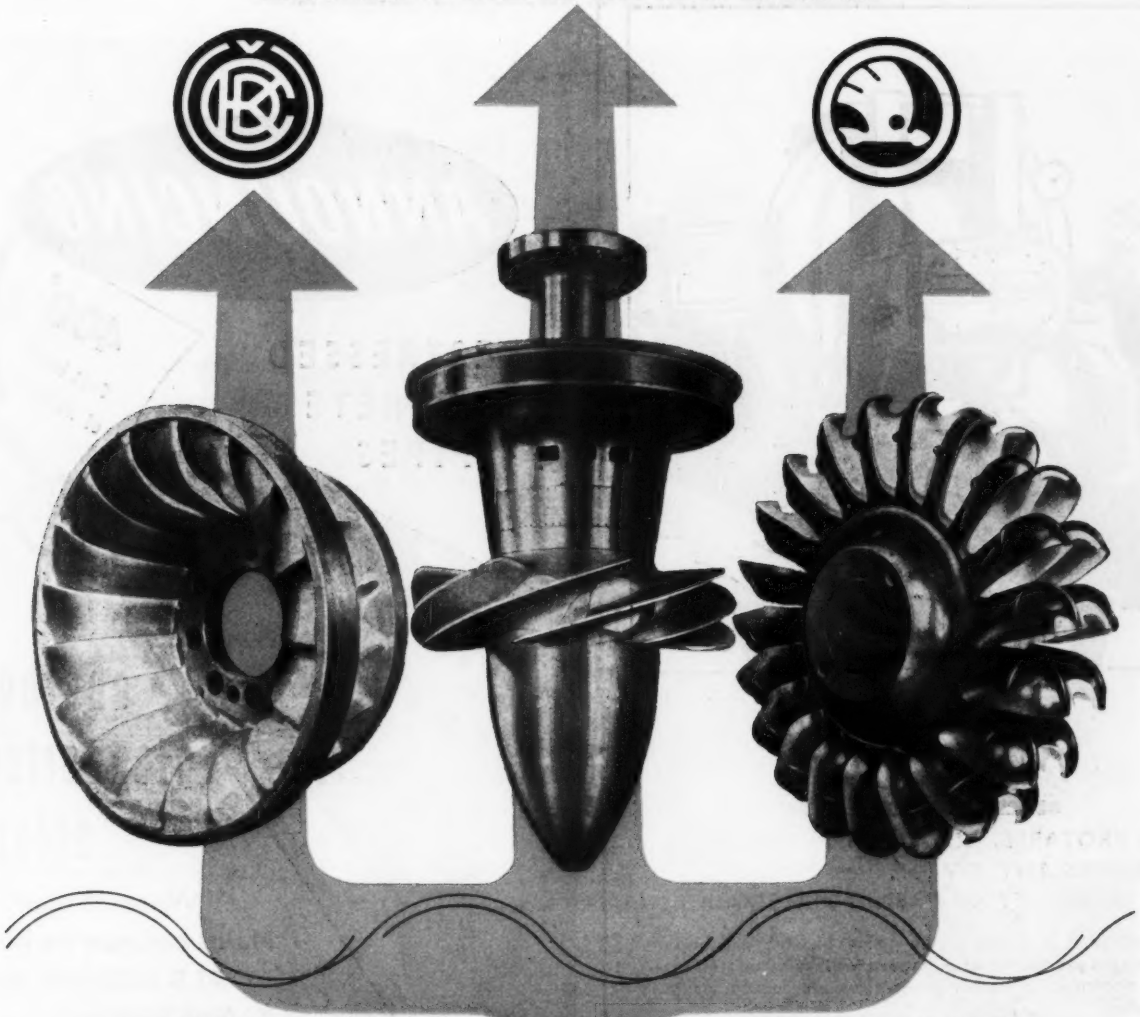
ASSEMBLERS & SOLE DISTRIBUTORS IN INDIA

THE UNITED PROVINCES COMMERCIAL CORPORATION

6, GANESH CHANDRA AVENUE, CALCUTTA

Post Box No. 2491

P.T.S./IS 2056



COMPLETE EQUIPMENT FOR WATER POWER PLANTS

Turbines of the Francis, Kaplan and Pelton type for various heads and outputs ; transformers, generators, outdoor and indoor switch gears, controlrooms, etc.

The world known SKODA and CKD Trade marks guarantee the first class technical design and quality of equipment supplied by us.

We give integral guarantees for complete deliveries.

We shall be pleased to advise you in all your problems connected with the projection of water power plants.

TECHNOEXPORT

FOREIGN TRADE CORPORATION FOR EXPORT OF COMPLETE INDUSTRIAL PLANTS

56 Vaclavske namesti, Praha II, Czechoslovakia

Sole Representative:

SKODA (INDIA) PRIVATE LTD.

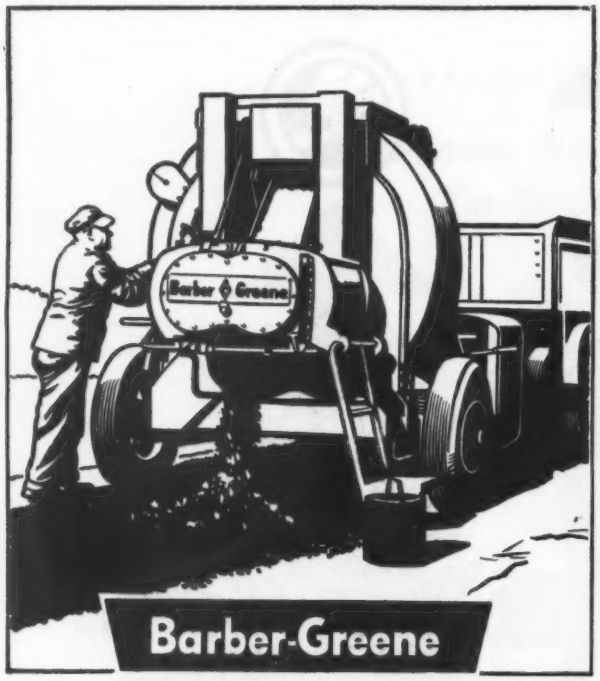
Head Office:

Vulcan Insurance Building, Vir Nariman Road, Bombay-1

Branches :

Delhi Stock Exchange Bldg., Asaf Ali Road, D.A.G. Extension, New Delhi

P 38, Mission Row Extension, Calcutta-13



Mixall

THIS PROTABLE, LOW-COST MIXER-DRYER PRODUCES ANY TYPE . . . ANY QUANTITY OF PREMIX MATERIAL

The Mixall is a small, highly portable unit, capable of on-the-spot production of all types of mixes comparable to those qroduced in Barber-Green's largest continuous hot mix plant.

MIXALL QUANTITIES... from a single 300-lb. batch up to 5 tons per hour of hot mix or 10 tons per hour of cold mix.

MIX IN ALL LOCATIONS... The Mixall can be towed by light trucks. Can be loaded from truck, wheelbarrow or stock pile. Works in a single traffic lane.

MIX STABILIZING MATERIALS using Portland Cement. **MIXALL IS EASY TO USE** Unskilled labor can operate Mixall with little training.

For the complete story contact your B-G Distributor.

Barber-Greene

Barber-Greene Americas, Inc., Aurora, Illinois, U.S.A.
Barber-Greene Overseas, Inc., Aurora, Illinois, U.S.A.
Barber-Greene Canada, Ltd., Toronto, Ontario, Canada
Barber-Greene Olding & Co., Ltd., Hatfield, Herts, England

"Ask Jacks about it"

William Jacks & Co. Ltd.

(Incorporated in England. Liability of Members Limited)
CALCUTTA BOMBAY MADRAS
Sole Agents for

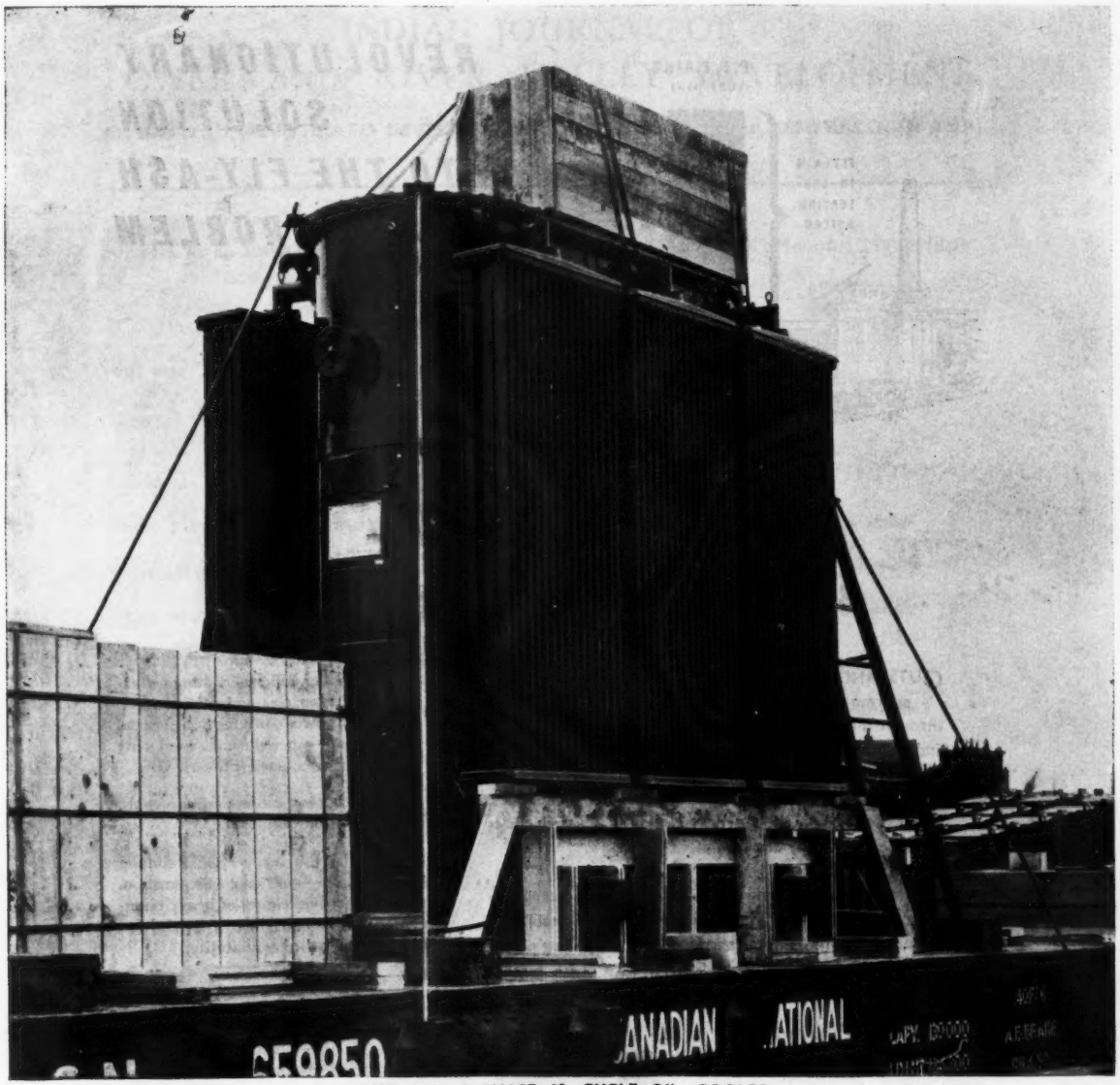
Barber-Greene Overseas, Inc. Aurora, Illinois, U.S.A.
Barber-Greene Olding & Co. Ltd. Hatfield, Herts, England.

No. 101—B.M.

ANNOUNCING
PRESTRESSED CONCRETE PIPES
400'
Feet head of water
another pioneering effort
Water Supply Mains can now be installed at a very low cost
* More Economical
* Truly Elastic
* High Tensile Strength
* Saving in Steel & Cement
* Lighter in Weight
* Easy for laying and Jointing
THE INDIAN HUME PIPE CO. LTD.

H. O. Construction House, Ballard Estate, BOMBAY—1.

Calcutta Branch, 190/1, Rash Behari Avenue CALCUTTA—29



3000 KVA 3 PHASE 60 CYCLE OIL COOLED
POWER TRANSFORMER 55°C 44000/4160 VOLTS.

The compact transformers built by "Supreme" today are lighter in weight and more efficient. And thanks to improved use of insulating materials, our present day models are far better than transformers built on the style of ten years ago.

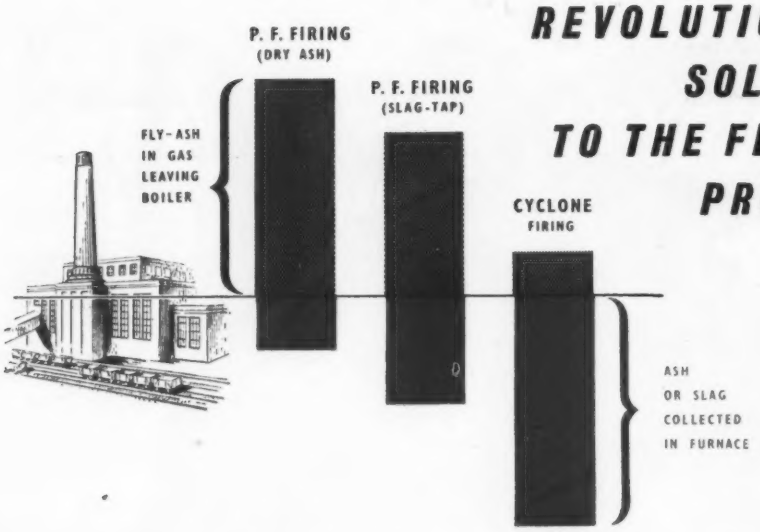
You save transformer time and money—and reduce failure rate—when you buy from Supreme Power Supplies!

Custom - Built Supreme Transformers are available up to 30,000 KVA at 138,000 volts.

SUPREME POWER SUPPLIES
LIMITED

2, Auldey Street, Mimico, Toronto 14, Canada.

Suppliers of Transformers for the Umtru Project.



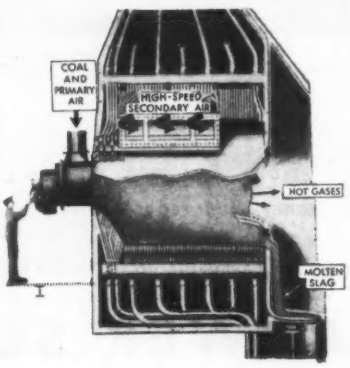
REVOLUTIONARY SOLUTION TO THE FLY-ASH PROBLEM

BABCOCK *CYCLONE* FIRING

OUTSTANDING advantage of the *Cyclone* furnace is the enormous reduction in quantity of fly-ash passing through the boiler. The major problems of ash collection and disposal and of stack emission are greatly simplified; while boiler efficiency and availability are increased by the reduction of slagging and deposits on the boiler surfaces. The *Cyclone* converts the ash to molten slag, which is quenched and easily disposed of.

A Babcock development, the *Cyclone* furnace, after many years of research and full-scale service, is now established as one of the most effective methods of coal-firing power station and large industrial boilers, with these further important advantages :—

The coal is borne into the water-cooled refractory-lined furnace by a stream of high-velocity primary air and meets a tangential stream of high-velocity secondary air, forming a vortex of flame in which the fuel is completely burned, the hot gases passing into the boiler. The temperature in the *Cyclone* is high enough to liquefy the ash which clings to the walls forming a continuous coating of molten slag, which flows out of the furnace and is tapped into a water-filled tank.



Highest boiler efficiency due to efficient combustion, cleaner boiler surfaces, and lower power consumption for coal preparation—since the coal need only be crushed or coarsely pulverized.

Burns even poor grade, high-ash coals, at high combustion rates.

Due to high ash recovery and simpler ash disposal and coal preparation, removes various causes of heavy maintenance and shut-down ; so further improving boiler availability.

Enables greater evaporative capacity to be obtained in less total space. Smaller boilers, with less ash and dust-collecting plant and other auxiliaries, can be housed in less costly buildings.

Ideally suited to simple, automatic combustion control. Safe in operation. Easily started up. Ignition stable under all load conditions.

Flexible operation to meet wide load variations. Can be arranged for alternative firing with oil or gas.

Babcock & Wilcox Ltd. in the U.K. have under construction and on order, a number of *Cyclone*-fired boilers for both power station and large industrial installations.

BABCOCK & WILCOX OF INDIA (PRIVATE) LIMITED

4, BANKSHALL STREET, CALCUTTA. **16, QUEEN'S ROAD ESTATE, BOMBAY.**

INDIAN JOURNAL OF POWER AND RIVER VALLEY DEVELOPMENT

A MONTHLY DEVOTED TO DEVELOPMENT OF POWER & WATER RESOURCES IN ASIA

Editor : K. K. Sinha — P. K. Menon : Mg. Editor

Vol. VII — **MAY 1957** — **No. 5**

CONTENTS

THE UMTRU HYDEL PROJECT, ASSAM	*G. C. Goswami*	1
THE CHALLENGE OF OUR WATERSHEDS	*K. S. V. Raman*	7
THE STORY OF THE CHAINAT DAM	*M. L. Xujati Kambhu*	13
EXPERIENCES OF THE FIRST FIVE-YEAR PLAN IN RELATION TO IRRIGATION AND POWER PROJECTS	*P. P. Agarwal*	15
SOME PROBLEMS OF DESIGN AND CONSTRUCTION OF EARTH DAMS—II	*Raul J. Marsal and Enrique Tamez G.*	18
DRAINAGE STUDY OF LOWER DAMODAR VALLEY—II	*Satyakam Sen*	25
THE MINISTRY'S REPORT	*Editorial*	41

In the coming issue :

Kangsabati Project *by* R. B. Chakravarty, M.I.E. M.Am. S.C.E. Project Engineer and Superintending Engineer, Kangsabati Circle; Some Aspects of Silting of Reservoirs *by* R. J. Garde, B.Sc. B.E., M.S. (Irri. Eng.) (Colorado) Jr. M.A.S.C.E; A Preliminary Investigation on the possibility of Flood Forecasting in Damodar Valley area by Statistical methods, *by* K. C. Mazumdar, M.Sc. D.Phil., Regional Meteorological Centre, Calcutta; Drainage Study of Lower Damodar Valley—III *by* Satyakam Sen.

Editorial and Managerial Offices
6/2, MADAN STREET, CALCUTTA-13. PHONE : 23-1765 & 23-5855. GRAM : TEKJOURN
Manager : B. Bhattacharya

Delhi Office	Bombay Office	German Representatives	London Representatives
18, Kakanagar Cornwallis Road New Delhi	41, Hamam Street Bombay 1 Phone : 252119	Intercont G. M. B. H. Frankfurt A.M. Kurfurstenstrasse 49	Walter Judd Ltd. 47, Gresham Street London E C. 2

Annual Subscription : Rs. 20, £2 or $6.00. *Single copy : monthly issue* Rs. 2

4 DIFFERENT EARTHMOVERS

AT YOUR FINGER-TIPS!

'International' Drott Skid-Shovels are already giving a spectacular performance in many industries, undertakings and projects in India.

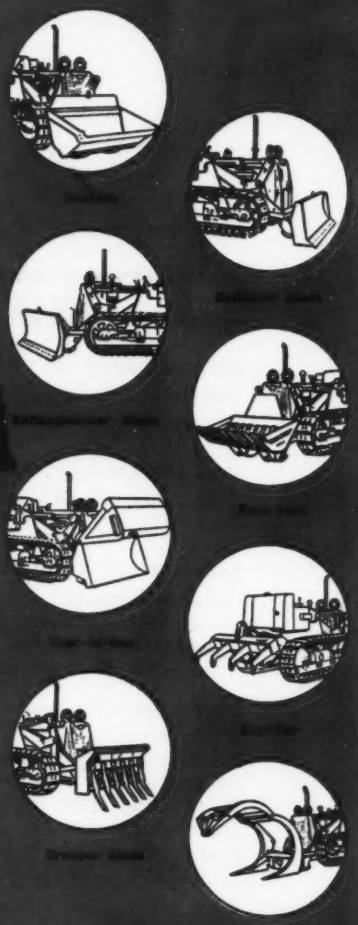
See the amazingly versatile Drott as soon as you can — there has been nothing in the earthmoving line to touch it.

Versatility unlimited!

Digging - Dumping - Grading

Spreading - Lifting - Compacting

DROTT DOES THE LOT!



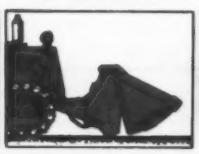
International

Drott Skid-Shovel with exclusive 4 in 1 Attachment

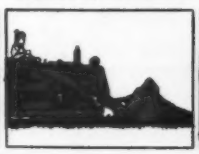
International Drott Skid-Shovel is the fastest, toughest, most versatile front-end loader in existence! When the unique 4 in 1 attachment is fitted in place of the standard bucket, the Drott is instantly convertible from the operator's seat to bulldozer, clamshell, bullclam or skid-shovel.

Responsive Bulldozer

Versatile Bullclam



Big-capacity Skid-Shovel



Many-purpose Clamshell

INTERNATIONAL CONSTRUCTION EQUIPMENT

INTERNATIONAL HARVESTER

Backed by **VOLTAS** *unrivalled service and spare parts organization*

VOLTAS LIMITED

BOMBAY · CALCUTTA · MADRAS · NEW DELHI · COCHIN · BANGALORE · AHMEDABAD · SECUNDERABAD · LUCKNOW

VOL.877

The Umtru Hydel Project, Assam

G. C. GOSWAMI
Chief Electrical Engineer, Assam

Gauhati, the premier town of the North-East State of India with a population of nearly a lakh is situated on the South Bank of the Brahmaputra river. The meter-gauge Railway line connecting Assam to the rest of India commences at a place called Pandu, the Regional headquarter of the N.E. Railway which touches the outskirts of Gauhati. The Borjhar air-port for the town of Gauhati is at the foot of the Khasi Hills. In the post-war period, Gauhati has become the nerve centre of the State with a new University, a High Court, an Engineering College, an Ayurvedic College, a Veterinary College, a Forest School, an Agricultural School, the All India Radio, etc., which have all sprung up in and around Gauhati. At no distance from Gauhati is also the famous silk town of Sualkuchi where the entire village of 14,000 population weaves the famous silk clothes of Assam in handlooms, losing every day in the battle with the outside competition which produces woven in power looms.

At a distance of only about 20 miles from Gauhati, on the foot hills of the Khasi Hills within very easy reach of the all-weather metal road connecting Gauhati to Shillong, there are a series of beautiful rapids in a gorgeous back-ground of orange groves, orchids and ever green bamboos on a river known by the name of Umtru which emerges to the plains from the hills collecting the rainfall of about 370 sq. miles of Khasi Hills bordering Cherrapunji, the wettest place in the world. The combined fall on these rapids is about 190 ft. on the average and flow on the Umtru varies from about 70,000 cusecs in high floods to about 150 cusecs in the dry months of April.

Umtru river

There is obviously a site for generation of a small block of power.

Hydro interest in these rapids of the Umtru river dates back to 1921 when Blenkinsop and others tried to make a hydro electric survey of the rivers of Assam but the investigations were left incomplete. It was again in 1946 that the rapids were re-surveyed and a project report and estimate was submitted to Government for acceptance but no finance was available for the project until in the year 1952. Mr. Robert Reid, the Canadian High Commissioner and Nik Cavel, Colombo Plan Administrator, Canada, took an interest in the project and paid a visit to the beautiful Umtru valley in that year. When they learned that the per capita consumption of electricity in the State of Assam is only about .74 kWh, and there is abundance of useful water falls on small rivers like the Umtru which are going waste and the people were starving for power, they agreed to bring in the aid of the Colombo Plan to the extent of about 1.5 crore in machineries and for construction of a small weir, a Power House, the High Transmission lines, Substations etc., for the benefit of the people living in the area around Gauhati.

In 1954, the Chief Electrical Engineer paid a visit to Canada to finalise the details of the machineries and equipments. The Central Water & Power Commission took responsibility for detailed design of the weir, the tunnel and the penstock and construction work began early in November 1954 on the weir and the tunnel and in February 1955 on the Power house. The Canadian equipment began to arrive in 1956 as scheduled. A high water and low water timber jetty was constructed at Pandu to receive the heavy materials from inland steamer on the Brahmaputra river during both high and low water period and then the machineries were shifted by road to the Power house site. The road bridges which were designed only for 12 tons had to be strengthened.

All the 33 and 11 kV transmission line materials were ordered from indegeneous sources excepting the insulators which were obtained from Japan. All the line supports were local sal wood poles. The erection of transmission line work and machines were done departmentally. The Canadian Government sent out two engineers, one Civil and one Electrical, who helped in technical matters and acted as a Liaison between the Government of Assam and Government of Canada.

View of River Umtru passing through deep gorge just above the Power House.

The construction work on this Umtru Hydro Electric Project has now been completed and the following is a brief description of this small but the first major Hydro Electric Project in Assam.

The Weir, the Tunnel and the Penstock

At the head of the rapids, the river water is impounded by a masonary diversion dam and diverted through a 4600′ long conduit system to the Power House located two miles down the river. The conduit system consists of two tunnels 2700′ and 830′ long connected by a steel pipe line of 705′. A 350′ long high pressure steel penstock pipe 1/2″ thick connects the second tunnel to the Power House. The pipe branches into 3 distributor pipes for feeding the 3 turbines in the Power House. In the middle of the second tunnel there is a high surge tank 32′ in dia. nearly 100′ high above the tunnel. The tunnel is of usual horse-shoe shape and its diameter is 9′-9″ and the diameter of the high pressure penstock is 8′ and the trifurcation pieces 4′, thickness being 1′/2″ throughout. Each unit has a butterfly valve fitted to the extension piece from the scroll case.

The diversion dam is built in random rubble masonry with dressed stone facing. The down-stream apron is in concerete laid masonry.

The overflow section of the weir is 350′ long, crest elevation being 404.50′. The bottom width from the axis of the weir to the end of the concrete apron is 92.87′. The non-over flow section is 60′ on the right abutment and 78′ on the left, elevation of both being 431.00′.

The salient features of the Civil Works are:

Total length of the weir	..	540′
Length of spill-way	..	360′
Maximum water level	.. EL	426.9′
Crest of spill-way	.. EL	404.9′
Minimum draw level	.. EL	390.0′
Maximum taill water level	.. EL	235.0′
Maximum gross head	..	198.00′
Minimum gross head	..	183.50′

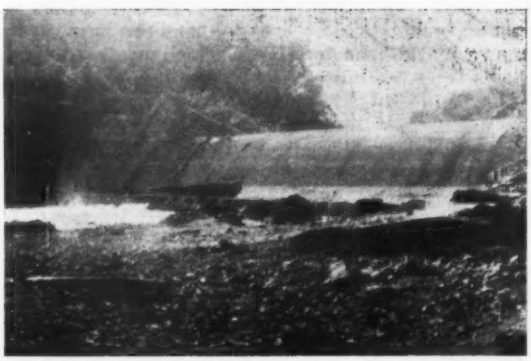
In the left abutment is situated the intake sluice 9′-9″×9′-9″ to the conduit system with a scouring sluice 6′-0″×8′-0″. The hoist of the intake gate is on a column high enough to take out the gate which approximately 6.5 tons. The following quantities of work are involved in construction of the weir.

Rock Excavation	=4.25 lac cu.ft.
Masonery	=7.95 lac cu.ft.
Concrete	=1.36 lac cu.ft.

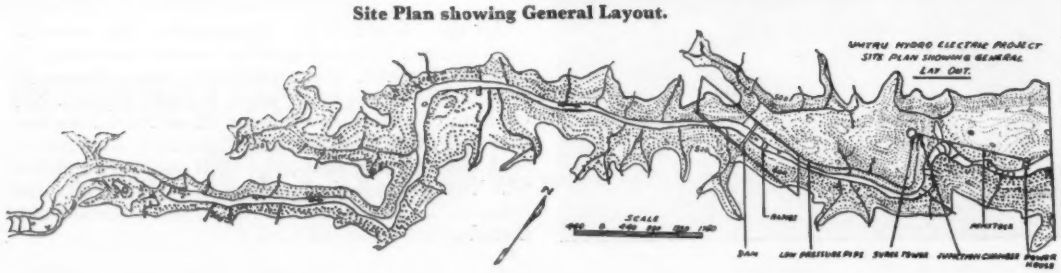
There are also concrete retaining walls on each side of the spillway.

The Power House is a partially submerged concrete structure 82′-6″ L×45′ B×64′ H. The walls are designed to withstand about 40 ft. water pressure. To avoid seepage of water copper sheets are used in construction of joints. The roof of the Power House

The Dam of Umtru Hydel Project



Site Plan showing General Layout.



SHOFU

H. T. SUSPENSION & PIN TYPE INSULATORS
USED BY
ASSAM GOVERNMENT ELECTRICITY DEPT.
FOR
OVERHEAD TRANSMISSION LINE OF THE

UMTRU HYDRO ELECTRIC PROJECT

——:O:——

ALSO

BUSHINGS - FOG TYPE - POST TYPE - INSULATORS, ETC.

Manufactured by **SHOFU INDUSTRIAL CO. LTD., JAPAN**

SOLE AGENTS IN INDIAN UNION

B. R. HERMAN & MOHATTA (INDIA) PRIVATE LTD.

19, BRITISH INDIAN STREET, CALCUTTA-1.

THE FIRST
OF ITS
KIND IN
ASSAM

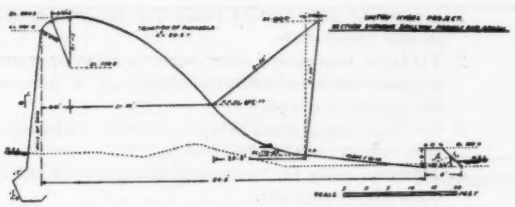
UMTRU HYDRO-ELECTRIC PROJECT

- MASONRY WEIR
- INTAKE STRUCTURE
- TUNNELS
- SUPPORTS FOR PENSTOCK PIPES
- POWER HOUSE

Construction by

HIND CONSTRUCTIONS LTD.

ENGINEERS & CONTRACTORS
8, INDIA EXCHANGE PLACE
CALCUTTA-1



Section showing Spillway Profile and Apron

is specially treated to withstand heavy rainfall of the monsoon with lime concrete plus two layers of water proofing paper painted with bitumen and covered with $1\frac{1}{2}''$ patent stone slabs.

An electirc driven gantry crane of 15 ton capacity is provided on a concrete column on the roof over the entrance to the Power House which is for handling the heavy equipments received for the Power House and lowering it through an opening in the roof to the main floor of the Power House. The main power house crane is of 19 ton capacity.

It will be noted that the maximum tail water level is 235′. The various levels inside the Power House in relation to this may be noted :

Sump pump floor	.. 200.00′
Bottom of draft tube	.. 200.50′
Valve Gallery floor	.. 203.88′
Turbine & Governor floor	.. 213.00′
Generator floor	.. 220.33′
Control room floor	.. 222.33′
Terrace	.. 236.00′
Main roof	.. 243.00′
Office and battery room roof	250.00′
Gantry top	.. 264.00′

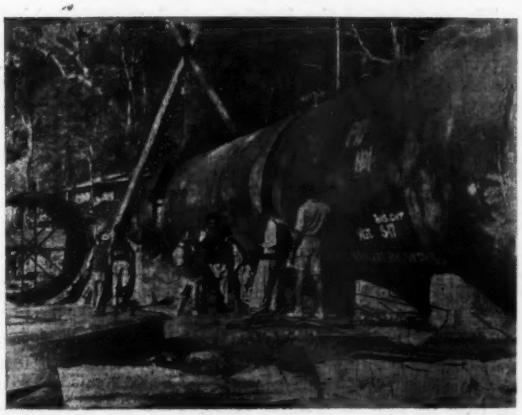
The machineries and equipments

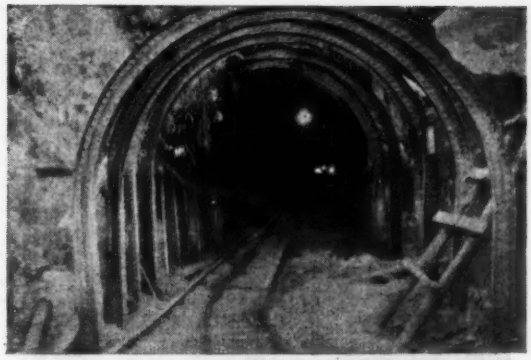
There are three 37″ Francis type 3500 H.P. vertical turbines operating under 175 ft. of net effective head running at 500 R.P.M.

The run-away speed under 200′ head at no load in the generator and turbine gate full open is 917 R.P.M.

Downward thrust due to weight of shaft and runner and hydraulic thrust totals about 23,000 lbs. under 200 ft. of head.

Steel Conduit in the Umtru Hydel Project





The entrance to one of the Tunnels in the Umtru Hydel Project

Bearings: The thrust bearing designed to support this combined weight is of spring supported type and is mounted on the upper bearing bracket.

The upper and lower bearing brackets are of farbicated steel spider type.

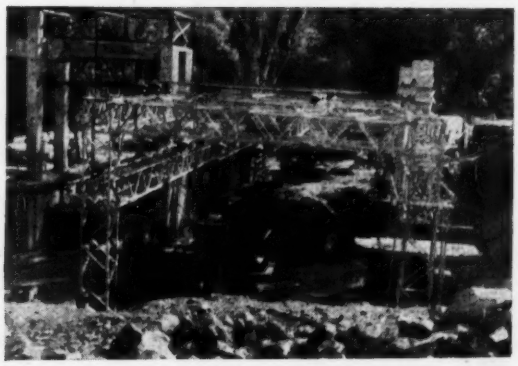
It will be possible to dismantle the thrust bearing by removing the exciter. The upper and lower guide bearing may also be dismantled without disturbing the thrust bearing or bearing brackets but to dismantle the upper guide bearing, it will be necessary to remove the exciter.

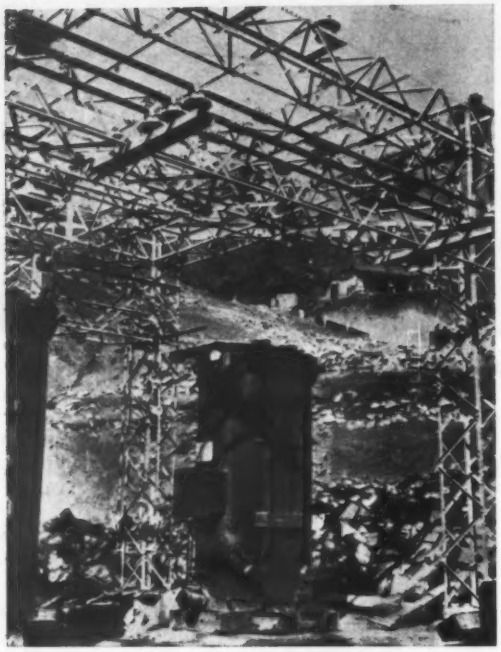
The draft tube liners extend 15′ below the centre line of the turbine. The Governor is 10,500 lbs. Wood-ward type.

The oil pressure operated Governor is equipped for complete automatic control of the prime movers with provision for manual control in the event of failure of the automatic equipment. The motor driven governor head receives its supply from the permanent magnet generator fitted over the exciter on the main shaft of the generator.

Generators: Vertical 12 pole, 3600 kVA. 0.8 p.f. 500 R.P.M. 330 volt, 614 amp., 3 ohm. 50 cycles WR^2 being 147,000 lbs per ft^2.

Power House & Switchyard combined in the Umtru Hydel Project





Umtru Power House Sub-station

The generator frame is welded steel supplied completely assembled with punchings and windings in place. The stator windings have class B insulation throughout and is connected in star with neutral leads brought out for differential protection.

The rotor spider consists of steel lamination securely bolted together and mounted on the shaft with a shrink fit. The field poles are dovetailed to the laminated rator spider. The field coil windings consist of copper strap wound on edge with class B insulation (asbestos) between turns. The shaft and the rotor are supplied assembled.

Exciter : Direct connected each rated at 20 kW, 500 R.P.M., 60 volt shunt wound and stabilised and is mounted on the upper bearing bracket of the generator, and is designed for operation with generator voltage regulator and also by hand control.

Cooling surface air cooler : Air is taken from generator pit expelled through holes in stator frame into sheet metal housing on two sides of the generator and returned through surface air cooler to the pit.

Electrical characteristics

Efficiency guaranteed with WR^2 147,000 lbs.
95.4% at full load
94.8% at 3/4 load
92.5% at 1/2 load

Regulation. .8 p.f. 27%
(calculated) 1.01 p.f. 15%

The generators have their neutral grounded through a reactor .45 ohm. 50 cycle, 1200 volt., 2500 amps. for 10 seconds single phase self cooled dry type. The field air circuit breakers 250 volts D.C. 600 amp. size are electrically operated from 125 volt D.C.

The main relays for the protection of the generator are :

1. generator differential relay for internal faults in the generators.
2. Voltage, restrained over current relay operates on generator overcurrent resulting in generator under voltage.
3. over current ground relay for current unbalance through generator neutral leads.
4. Thermal relay for increased resistance of stator coils above normal.

The switchgear and control equipment are located on the control room floor as follows (looking from left).

1. (*a*) Synchronising panel with synchroniscope on 110 volt coil with frequency meter, volt meter 3300/110 etc.

(*b*) Annunciater panel with flash light and audible alarm on occurrence of fault, push buttons etc. for alarm cancellation.

2. Surge protection cubicle with lighting arresters for generator surge protection directly grounded neutral type 3.3 kV.

3. Exciter cubicle with *Brown-Boveri* voltage regulator, voltage adjusting rheostant etc.

4. Generator breaker cubicle with oillers, breakers 5 kV. 800 amp draw out type 3 pole trip free complete with 125 volt D.C. closing coil shunt trip coil, operation indicator counter etc. etc. interrupting capacity 150 MVA at 3.3 kV.

(3) and (4) one each for each generating unit.

5. Transfer breaker cubicle. Containing one power circuit breaker oil less .5 kV. 2000 amp., draw out type 3 pole complete with 125 volt D.C. closing coil etc. etc.

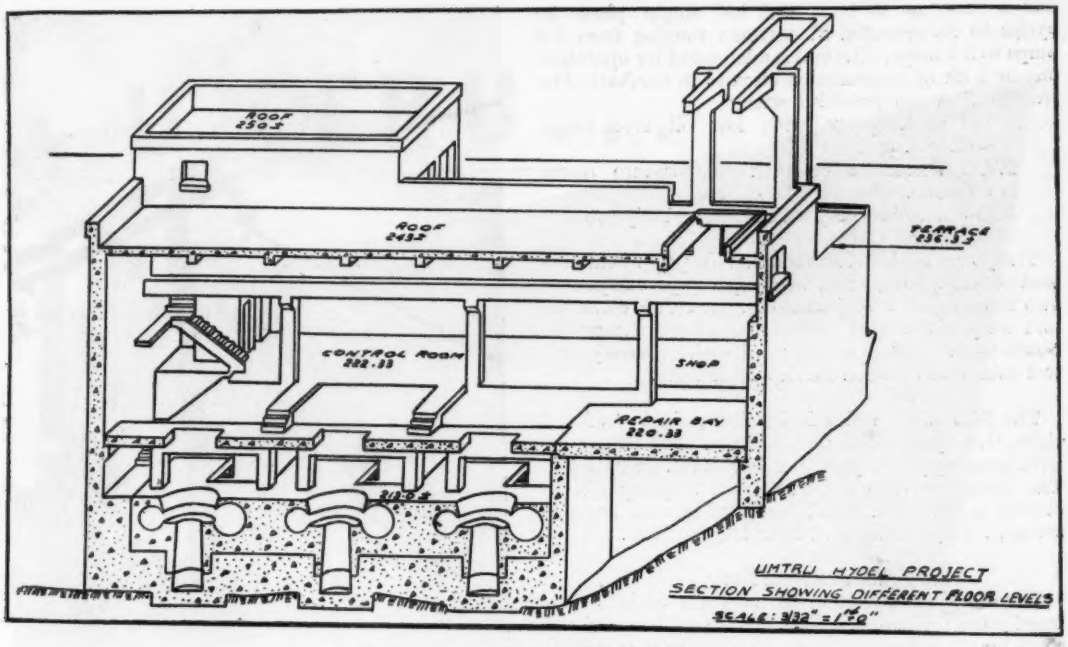
6. Station service cubicle. Containing disconnecting switch 3.3 kV. 3 pole gang operated for 150 kVA for station service and colony feeder.

7. Station service distribution Panel Board. With one thermal main breaker 200 amp., 3 phase 400 volt with thermal and magnetic trip and 20 such thermal type small breakers with thermal and instantaneous trip attachment for various consuming apparatus.

The position of the Station switch-yard is behind the power house at an elevation of 236. The station service transformers are 2-3 phase 75 KVA. 3.3/.4 kW which are housed in a structure adjacent tomain switch-yard. In fact the platform of the station service structure is over the top of the left branch of the penstock which is covered in concrete and back filled for installation of the station service.

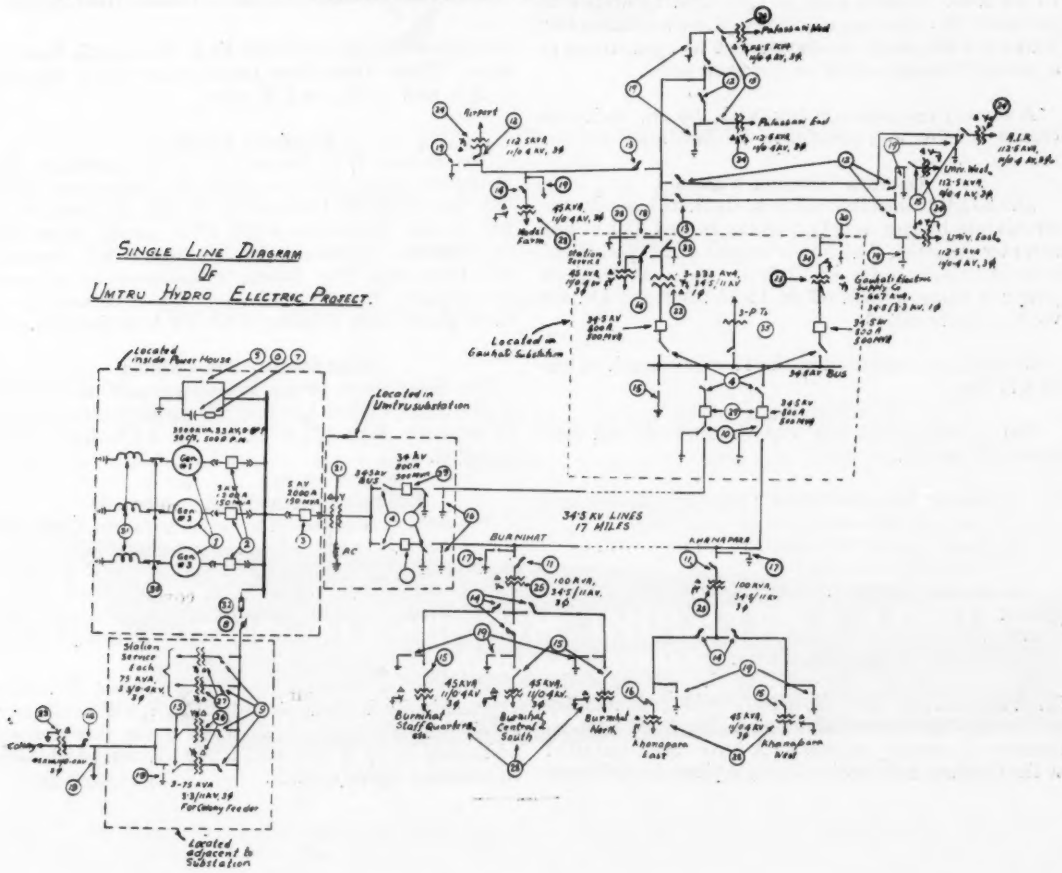
Step up transformer

The agregate machine capacity of 10,500 kVA. generated at 3.3 kV., 50 cycle 3 phase is stepped up to 34.5 kV. in a bank of 3 single phase transformer of 3500 kVA delta/star connected. The neutral of H.T. side of the transformer is grounded through a peterson coil to minimise the ground fault current. There is provision for an annunciator on the control board in case of line to ground fault. This are supersion



Section showing different floor level

Single line Diagram of Umtru Hydel Project



coil is rated at 99 kVA 33/3 kV single phase 50 cycles to be operated at currents ranging from 5.2 amps to 2.2 amps. The coil is adequated for operation one or both of transmission circuits to Gauhati. The transformers are provided with :

1. Oil level gauge with low oil level alarm contacts.
2. Oil thermo-meter with temperature alarm contacts.
3. Gas detector relay with alarm and trip contact.

The power cables of size 3/0 S.W.G. paper insulated lead covered, compound, two paper taps compound, two brass tapes, PVC jacket etc. for 5,000 volts, are laid on prefabricated cable trough from the switch board to the outside switch yard with necessary control cables and station service cables. etc.

The 34.5 KV oil circuit breakers, single tank oil tight, three pole single switch are rated at 600 amps. with interrupting capacity of 500 MVA. at 34.5 kV. The breakers are solenoid operated spring charge closing machanised rated interrupting time being 8 seconds. Trip coil is rated from 125 volt D.C.

Transmission line

The 23 kV. transmission line supports are local Salwood poles free from sap wood 35′ to 40′ long and the route length is approximately 17 miles to the Gauhati terminal station. The A.C.S.R. conductors equivalent to 0.04 sq. inch copper are used. Normal span is 300 ft. to 350ft. Maximum span used is 900ft. in between hills. Tension used is 1,500 lbs. Clearance to ground is 20′. Clearance between phase conductors 4′. There is a telephone conductor on 6 kV. pin strung at a ground clearance of 13′ on the same poles.

A second transmission line with .05 sq. inch conductor is being laid parallel to the first line.

Gauhati Terminal Station

The 33 kV transmission line to Gauhati has only one circuit now but construction on the second 33 kV. line is under progress. The line is tapped at 2/3 points enroute to Gauhati for small local loads. At Gauhati power is being tapped off at 11 kV. and 3.3 kV. for various load centres.

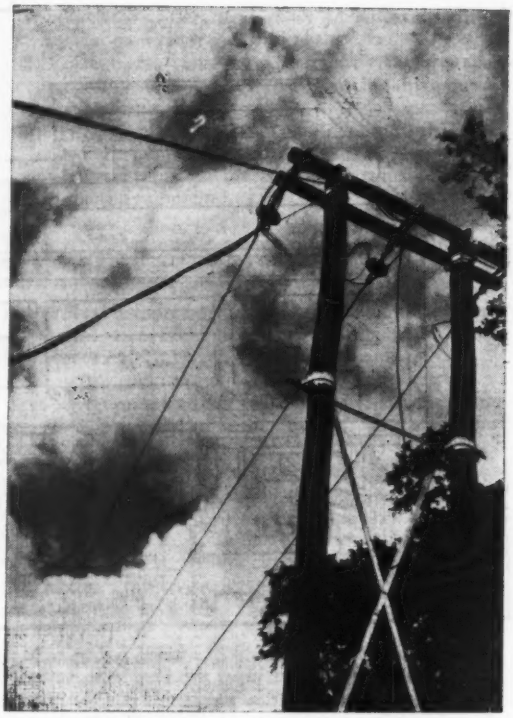
No earth is being used in the 17 miles length of the 33 kV. line.

The control switch board at the Gauhati end consists of 3 panels.

1. Control panel for 34.5 kV lines with directional over current relays and ground relays.
2. Control panel for 3.3 and 11 kV lines with same type relays as above.
3. Annunciator and station service distribution panels.

Gauhati Feeder

The most important feeder in the system is the Gauhati license feeder where 35% to 40% of the entire generating capacity willl be used. For this 4 transformers of capacity of 666 kVA have been installed at the Gauhati Sub-station 3 single phase transformer



Wood Pole Transmission line in Umtru Hydel Project

in a bank will deliver 2,000 kVA, the fourth being a spare. These Delta/Star transformers have tapping $\pm 2\frac{1}{2}\%$ and $\pm$ 5% on L.T. side.

Palasbari Feeder

The Second H.T. feeder line in the system is the Palasbari feeder line in which the important loads like the Gauhati University, A.I.R., Railway etc., will be on. There are 4-333 kVA single phase, 50 cycle number of transformers 20-34.5/11 kV. Connected Delta/star. The fourth transformer is a spare transformer. These transformers are to be used in a three phase bank totalling 1,000 kVA on this line.

Other Smaller Sub-stations

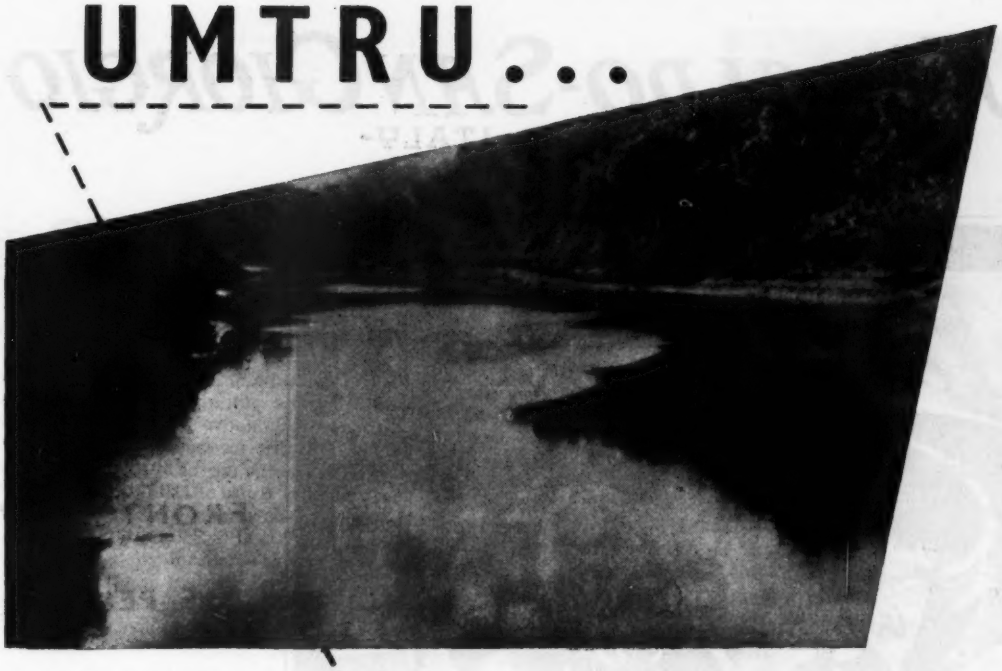
For distribution of energy at various centres both on the 33 kV and 11 kV line. 27 transformers ranging in capacity from 125 kVA to 45 kVA have been installed.

Estimated demand and energy sale

The station is expected to be loaded upto 5,000 kW soon after it is commissioned. Estimated energy to be sold being approximately 18.5 million units, which is expected to fetch in a gross revenue of Rs. 10.9 lakhs. Nett revenue expected is Rs. 13.0 lakhs approximately, present return on sum at charge being 5.45%.

The Umtru Hydel Project costs about Rs. 2.26 crore. The load to the extent of 5,000 kW is already subscribed. Provision has to be made now for an additional block of power of 5,000 kW for which also the demand already exists.

UMTRU...



. . . first major hydro-electric project in Assam

From a dream in 1921, the Umtru Hydro-electric Project is today a reality. A small, but significant, project, its completion will mark the beginning of a new era of "power" and prosperity for the people of Assam.

AL-IND

ALIND is proud of its association with this project. A total length of 106 miles of conductors has been our contribution to it.

THE ALUMINIUM INDUSTRIES LIMITED

KUNDARA, KERALA STATE

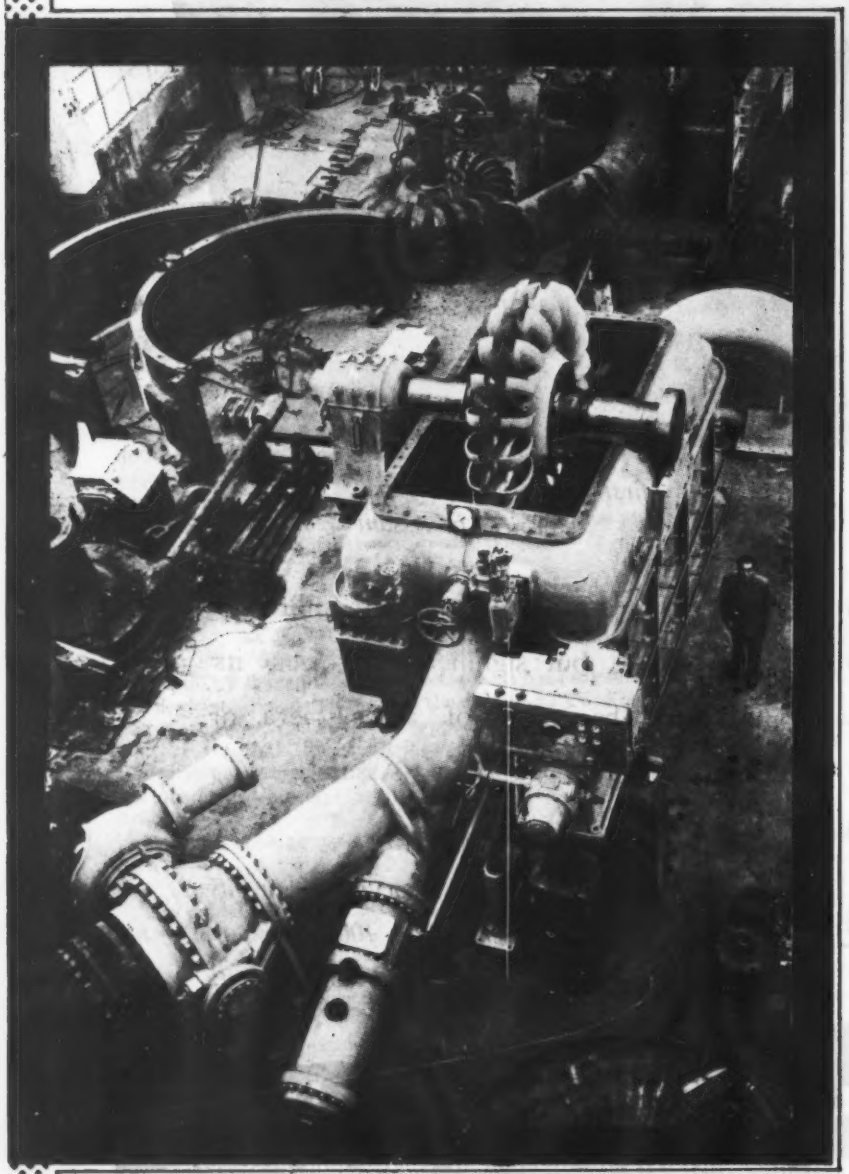
India's largest manufacturers of aluminium cables and accessories

Managing Agents: **Seshasayee Bros. (Trav.) Private Ltd.**

AL-375

ANSALDO-SAN GIORGIO

GENOVA-ITALY-



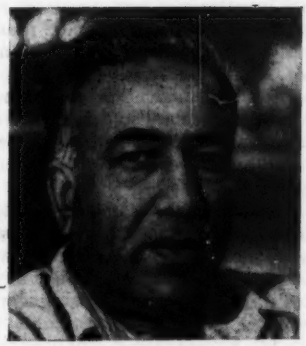
FRONT VIEW OF PELTON TURBINES FOR EROMA POWER STATION -SICILY- WITHOUT COVER IN THE WORKS

Agents for India :

KAMANI ENGINEERING CORP LTD

BOMBAY • CALCUTTA • MADRAS • NEW DELHI

SPHINX 25



The Challenge of our Watersheds

By K. S. V. RAMAN, I.C.S.

The need for water has attracted human colonies to river banks from the beginning of man's history. Aqueducts, public baths, urban drainage, diversion of water from flowing rivers for irrigation and water mills, have all been known from the earliest days. The idea that deforestation in the upper reaches upsets the river's regime and causes floods in the lower reaches is at least as old as Plato and Buddha. The domestication of animals followed by intensive grazing of pastures started early in human history. This may have contributed to the elimination of plant life in areas round about some ancient colonies and the progressive detereoration of such areas to deserts. Increase in human population and the quest for food, fuel and timber and forest produce have led to widespread deforestation from the beginning. Colonisation of new countries and deforestation with mechanical means have caused widespread destruction in the last century or two. The attacks through intensive grazing has continued all through. The direct linking of the changes in plant cover and run off, attributable to changes in land use in the upper reaches, with the river regime lower down and an attempt to work towards comprehensive better use of land and water in the entire watershed as an integrated area of operation are, however, comparatively recent developments.

In the entire watershed of a typically large river, physical, social and enconomic environments vary a good deal. The clear water of a mountain brook issuing from a glacier has little in common with the silt laden flood flows in the deltas near the sea. In the hills, forests, pastures and terraced cultivation dominate, irrigation has little scope and domestic consumption is the main use of water. In the escarpments hydro electric power generation from drops of water is possible, the economics of which are largely dependent on the need for power within reasonable distances. In the middle and lower reaches and in the deltas are dense populations engaged in intensive agriculture and industry and in contact with the rest of of the world, with sophisticated patterns of living. Hence stress is often largely on the aspects of flood control, irrigation and industrial and municipal uses of water and navigation. Often ethnic variations occur in a large watershed with the more primitive sparse populations occupying the inaccessible high lands under economically and physically tougher conditions of living, having little in common with the urbanised life in the lower reaches. Such people in the upper reaches have a quite different approach to man's relations with his fellow men and the community from those that prevail in the populous lower reaches. The common waters may well pass through different countries with different levels of political and administrative efficiency and different ideologies. Even within a country a river often passes through different federating units of administration with different types of administrative set-up and local laws regarding the use of land. In fact often the two adjoining deltas of large rivers have more in common between themselves than with social and economic conditions, patterns of living and physical environments prevailing in the upper reaches of their own rivers. The only common thread that runs throughout a river valley, however, is the passage of the common waters precipitated in the entire watershed. Such common factors that arise out of the common waters, however, justify the unity of a watershed. Water problems necessarily involve problems of soil, of power generation, irrigation, flood control, navigation and industrial and municipal consumption of water and these require a co-ordinated approach. These cover such a large and important part of human activity and the economics of co-ordinated development produce such large returns that watershed development as a whole has come to the front.

The ultimate purpose of the development of watershed is to increase the economic and social welbeing of the people of the basin in particular and of the nation as a whole. The Missouri River Basin Agricultural Programme contemplates to :—

"(*i*) Protect, conserve, and improve the lands of the basin for more efficient production and use by acceleration measures to conserve soil and moisture on farms, grazing lands, farm woodlots, and forests ; the improvement and increase of timber, range, and wildlife resources ; the enlargement of recreation opportunities ; the planting and care of additional shelterbelts and extension of the shelterbelt area ; the constructive rehabilitation of detereorating lands and their conversion to better adapted uses ; and the installation of other measures found necessary to contribute to productive and profitable land use.

(*ii*) Protect and enhance the water resource originating on the watersheds of the basin, thus contributing to irigation, navigation, power,

domestic and industrial use ; to fish and wildlife, and recreation ; to pollution abatement ; and to other productive uses.

(*iii*) Establish watershed practices and measures to aid in reducing flood and sediment damages, protect and effectuate large investments in water-development structures, and safeguard farm lands, farm and urban property, railroads, and highways from flood and sediment damages.

(*iv*) Enlarge and improve the agricultural productive capacity of the basin by irrigation and drainage wherever this will improve and stabilize incomes not only for farm people, but also for the communities of which they are a part.

(*v*) Extend the use of electricity to rural areas.

(*vi*) Expand agricultural research, investigations, and surveys that are designed to give direction to resource development and use ; solve problems arising from changes in land use ; and discover production practices that will improve use of the soil and water resources and prevent their impairment.

(*vii*) Intensify the agricultural extension activities to assist rural people to make maximum use of lands newly developed for irrigation and protected from floods by levees and drains ; to make the best use of electric power ; to apply accelerated land conservation and flood reduction measures ; and to adjust farming to new crops, new markets, and new methods."

The development of a watershed usually however starts with the need felt for power, industrial or municipal water supply, flood control or irrigation in the lower or middle reaches of a large river. The normal pattern has been for the engineering surveys of a particular project to be made based on existing data of hydrology and silt flows. Notwithstanding all the theories of costs and over-all benefits, the economics of most such projects are based on their direct costs and returns or in the alternative their strategic or political necessity irrespective of econonomics. Once the funds are appropriated, the project starts and they cannot be stopped half way and the tendency to under-estimate costs at the beginning to secure early sanction seems universal. Political reasons demand that expenditure of public funds in a country should be distributed some what equally over the entire State and this conflicts with concentration of work in the well planned development of a whole valley in one part of the country, even though such concentration is the most economical to the nation. Once, therefore, the estimated revenue of a project is accepted as satisfactory and it is sanctioned there is reluctance to appropriating more funds for the development of the entire valley even though such appropriations may lead to a much higher return of the investments by improving the returns from existing investments or securing significantly better economy by combining new projects with the sanctioned ones. The net result often is the development of the individual project with incomplete survey and development of the watershed as a whole. Financial investments become lopsided.

Another aspect of such uneven development without a correct background of the problems of the watershed as a whole leads to the mortgaging of an undue share of water to particular uses much in excess of what an overall survey would indicate as desirable. As and when demands for water increase, as they must every where, the most economical and equitable distribution of water becomes difficult with prior rights fully established. The total availability of water depends on the total precipitation. Such precipitation, however variable from year to year, is more or less steady over long periods exceeding say half a century or so, persistant trends of increase or decrease, if at all, being very small. This precipitation constitutes the total supply for the watershed to meet all the demands of absorption in the soil and transpiration by the flora, evaporation, charging the subsoil and ground waters and the surface run off through the river basin and consumption by men and fauna in the watershed. Larger consumption per capita for municipal purposes is the general trend with rising standards of sanitation. As a cooling or carrying agent or as an ingredient in the process, the demand for water from industries is progressively increasing. These municipal and industrial uses are intensive and can well afford a high cost of water as investments are large and returns high. Agriculture, however, is still the largest user of water but by its very nature cannot afford to pay high costs. It is roughly estimated that 65,000 gallons of water are required to manufacture one ton of steel, eighty gallons for each kilowatt hour of hydroelectric energy and 1,60,000 gallons to grow a ton of wheat. A small part of irrigational water goes to charge the underground supply and another part drains back to the river basin. Navigation in the lower reaches is another claimant which demands continuous steady level of water in the river. Hydro-electric generation uses only the fall but returns the water to the main stream after generating the power. Recirculation of water for cooling and other purposes saves consumption in the industry. Thus water for industrial use can be re-used, the water used for irrigation is lost through evaporation and transpiration and very little quantity goes to replenish the ground water storage. As demands increase the total availability remaining the same, the demands compete and shortage becomes visible. Conflict also arises in the pattern of consumption during the year. Hydro-electric power requires a continuous discharge and so does navigation and much of industrial consumption. Agriculture needs regulation in accordance with the needs of the crop and the precipitation during the different parts of the year. Variations in precipitations are most noticeable in South and East Asia where the monsoons bring in during the course of three to four months a very large part of the water supply leading to floods and unutilised flow of a large part of the water to the sea. The maintenance of the river regime in the lower reaches and, in particular, reduction of water flows to the river bank capacity during the flood season and adequate supplies for flushing to keep the mouth of the river open for navigational purposes and drainage during the rest of the year require controlled discharge. All these factors render necessary the storage of water during and after precipitation for use during the drier parts of the year and sometimes the carrying over of a wet year's extra supplies to lean years that follow. The increasing need, therefore, for effective water retardation process will be obvious. Large flood flows create the wrong

impression of unlimited availability of water. Large storages depend on topography and may not always be available in adequate quantity or at reasonable costs. The recent shortages and power cuts in the watershed of the river Kaveri in South India, where the utilisation of the total water potential is being approached is an instance of demands exceeding total availability of water in leaner years. This may well become the case of many watersheds in the East in agricultural and industrial development continue to make rapid progress.

Use of water is intimately connected with the use of land. The forms of soil erosion through the agency of water are many. Gully erosion, sheet erosion, and river bank erosion are well known. Top soil is carried away impoverishing the lands in the upper reaches, clogging the reservoirs on the way and fouling the river regime in the lower reaches. Such erosion leads to progressive deterioration of plant cover and increasing rates of run off with intensive peaks flow after each precipitation. Most of the problems of land use come in, flora and fauna are affected for the worse as also agricultural operations both in the upper reaches through the loss of soil and in the lower reaches through the increased floods and deposits of silt and sand. Progressive dessication often gives rise to wind erosion. Suitable sites for major reservoirs are not available in unlimited numbers. Their silting leads to progressively lessening heights of operations with diminishing output for the hydro-electric schemes and increased dead storage as well as flood margins and renders the economics of such reservoirs rapidly less attractive. Thus the only common link of a watershed, namely, the common run off of precipitation, has far more profound and far reaching effects than would appear in the first instance.

Approach to the development of a watershed would, therefore, seem to lie in the integrated use of the total water available according to the best possible coordinated programme taking into consideration all the present and future likely uses of water in that watershed. The basic nature of the development would be to retard the flow of the water throughout the year as well as from one wet year to the next so as to meet the varying patterns of consumption some of which require a steady supply throughout the year and some other larger quantities during certain parts of the seasons. These retardation measures are various. For purposes of classification they can be divided between measures that are largely biological in nature and others that involve engineering, while a large number involve both. Again certain measures are most suited to numerous smaller streams flowing through the usually higher slopes in the upper reaches as contrasted with the larger projects dealing with the main streams of the river in the lower reaches. But it is essential to emphasise that whatever may be the classification and nature of these water retardation measures the highest economic return can only be secured by making up as complete a picture of coordinated ultimate maximum uses of the water in the watershed as a whole so as to derive the greatest benefit from the available waters both in the surface run off and in the underground supplies. It is this linking of the different projects that makes the overall development more economical than is otherwise possible and also tends to maximum utilisation of all the waters. All water retardation practices in the upstream can be of the greatest benefit to the engineering works below and this seems to need special stress. Effective soil and water conservation measures in the forests, pastures and agricultural lands falling in the catchment of an upstream reservoir renders that storage capable of dealing with a larger catchment than would otherwise be possible. Such a reservoir may well serve for municipal use of a neighbouring small town or irrigation of a small patch of area commanded by it or it may be used for protection of wild life and for fishery. The controlled discharge of several such reservoirs can significantly increase the capacity of a larger reservoir below for hydro-electric or irrigational purposes and also flood control to a limited extent. The same water could well be dropped through one or more hydro-electric power houses lower down the river all the way and also be available for irrigation, human or industrial consumption or navigation. The soil conservation practices would significantly contribute to greater agricultural output in the form of forest, pastures or agricultural land. Where the topography affords a high drop for hydro-electric purposes but does not permit a large storage, numerous upstream reservoirs can take over that function. All the water retardation practices help in reducing the peaks of run off after heavy precipitation and hold back much of the silt cutting down the dead storage and flood margins necessary in reservoirs and better utilisation of the river bank capacity in the lower reaches over a larger period of time thus helping in the better maintenance of the river regime in the delta. The accurate economic assessment of individual contributions of these numerous small and large measures, biological and engineering, to the development of the watershed as a whole is extremely difficult. But what will be quite apparent is that such correlated measures greatly improve the economics as a whole.

In his message on the State of the Nation dated the 10th January 1957 to the U.S. Congress, President Eisenhower calls attention to the need for the judicious use of water resources and says :—

"I would like to make special mention of programmes for making the best uses of water, rapidly becoming our most precious natural resource, just as it can be, when neglected, a destroyer of both life and wealth. There has been prepared and published comprehensive water report developed by a Cabinet committee and relating to all phases of this particular problem.

"In the light of this report, there are two things, I believe, we should keep constantly in mind. The first is that each of our great river valleys should be considered as a whole. Piecemeal operations within each lesser drainage area can be self-defeating or, at the very least, needlessly expensive. The second is that the domestic and industrial demands for water grow far more rapidly than does our population.

"The whole matter of making the best use of each drop of water from the moment it touches our soil until it reaches the oceans, for such purposes as irrigation, flood control, power production, and domestic and industrial uses, clearly demands the closest kind of co-operation and partnership between municipalities, states and the Federal, state and local authorities in these vast projects we can obtain the economy and efficiency of development and operation that spring from a lively sense of local responsibility.

"Until such partnership is established on a proper and logical basis of sharing authority, responsibility and costs, our country will never have both the fully productive use of water that it so obviously needs and protection against disastrous flood." Additional arguments in favour of treating great river valleys as a whole would seem unnecessary.

The development of a watershed as a whole requires knowledge of its working as it is and its resources in water and land besides the human resources. The larger river systems of Asia start from the Central Asian and Tibetan plateaus and flow in all directions. The exceptions are the Euphrates and the Tigris which arise from the Taurna and flow through areas of little rainfall to the Persian Gulf. The northern rivers Yenesi and Lena flowing into the Arctic sea and the Amu Daria and Syrdaria that fall in the Aral pass through sparsely populated areas of little rainfall. The rest of them, chief among which are the Hwang Ho and Yangtsekiang of China, Meekong of China and Siam, Irrawady of Burma, Brahmaputra of Tibet, India and Pakistan, the Ganges in India and the Indus of India and Pakistan flow through areas of seasonal rainfall and as such are very variable in their discharge throughout the year. The snow fall confined to the upper most reaches of these rivers is not significant. The bulk of the waters are picked up well below the snow line. Measurements of rainfall furnish the basic data. Installation of rain measuring devices in adequate numbers and distributed to assure a correct sampling of different intensities and patterns of rainfalls in the different areas is essential. Besides the total daily, monthly and annual precipitations the intensity of storms over shorter periods that affects the peaks of run off greatly is equally important though often less measured. Automatic gauges which can be attended to over long periods of a month to six months at a time are of the greatest value in inaccessible areas of mountains or forests to which communications are difficult during the rainy seasons. The substitution of somewhat unreliable local agencies at various places by the automatic gauges attended to at fixed intervals by small but competent and responsible staff is badly needed. Data are particularly lacking in measurements of run off of water and of silt not only from experimental run off plots of various sizes but from different catchments of varying sizes with different types of natural land cover or crops. Such measurements at or near the confluence of tributaries and streams of the main river will give a correct picture of each individual catchment. Analysis of the total run off of water and silt following different types of storms and the different types of land cover over a large number of cases will indicate the most efficient type of land cover prevailing which could be extended with advantage. The correlation between the precipitations over the month and the year with the total precipitation based on the weighted rainfalls over the areas commanded by different rain gauge stations needs greatly to be improved ; also run offs after individual storms. The more extensive these data and more accurate they are the greater the scope for reducing the safety margins of structures, leading in some cases to great economies. Another factor of some importance in those areas where the climate is hot or dry during certain parts of the year is the collection of reliable data of evaporation losses in reservoirs. In small shallow conservation ponds evaporation might well become the dominating factor.

Land resource studies in watersheds cover a very wide field. There is the question of mapping the existing land use patterns. Where areas are great or inaccessible air maps and photographs are of great utility. Soil, topographical and ecological studies lead to the construction of soil capability maps. The soil and water conservation measures necessary will have to be based on these and will lead directly to planning of better land use. Existing social and economic traditions and complicated questions of land tenure and agrarian reform come into the picture of land use planning. By and large the initial stages would consist of dividing the land uses between the main classes of forestry, grassland and agriculture. Private ownership can impose serious limitations. Biological retardation measures like strip cropping, crop rotations and agronomical practices and shelter belts are of great value. Also the different types of terraces, ditches and contour cultivation necessary for retardation of water and silt. These have to be designed on local data. Local crops and agricultural and economic practices will greatly affect the measures recommended for local application. It would obviously be impossible to collect all the necessary data or to complete all the necessary research in order to enforce a proper land use pattern over the whole watershed, nor can the development of the watershed as a whole wait for a complete detailed picture. Survey and research have to be done by stages and reforms in land use introduced side by side. The correct discrimination between the essentials and the finer points of technology on the one hand, the pace of social education possible and the limitations of resources in finances, skills and adaptability on the other determine the form and rate of progress in improving land use. Programmes of great variety involving many technologies have to be co-ordinated with changing social and economic patterns of living. To evolve such programmes by stages as resources in manpower, machines, materials and funds permit while keeping in view the ultimate picture and working towards it is a difficult task that requires vision, faith and much administrative skill. It has been well said that no one "has the right to undertake any public activity unless he is thoroughly imbued with the sociological point of view, has developed an intergrated outlook on life and can see the entire complex of forces physical, biological, psychological, moral and spiritual moving together as a dynamic interacting whole.' This applies particularly to river valley development.

Forests serve as protection forests as well as productive forests and the distinction has to be clearly perceived. Erodible soils and steep slope have to be under protective forests. "The primary object of management of such forests should be to utilise in full their protective influence on the soil, the water regime, and the physical and climatic factors of the locality ; and the interest to be thus protected should far outweigh those which it may be necessary to restrict."* A good forest implies an effective canopy of leaves and a continuous ground cover of dry leaves and humus over soil in good condition. The canopy takes the impact of the rain and intercepts a portion of it. The wetting of the leaves, the branches and trunks of the trees econourages evaporation and the total amount intercepted before it reaches the ground can

*Government of India Forest Policy. Editorial, *Journal of Soil and Water Conservation.*

be a considerable part of the total precipitation over the forest. The temperature varies less inside the forest and the interception of direct solar radiation contributes towards this. A higher humidity prevails. The soil covered by litter and humus and shaded by the trees is cooler in summer and warmer in winter. Loss of soil moisture by evaporation is reduced both by the ground cover as well as the tree tops to nearly a third or half the evaporation from exposed soils outside the forests. Such soil protected by the litter is estimated to hold nearly twice its weight of water and the standing litter of decomposing matter makes for continuous percolation and better soil conditions. Wind velocity is lost inside a forest reducing evaporation and wind erosion. While it is doubtful whether forests do increase the total amount of precipitation over themselves as well as the neighbouring areas, they certainly help in conserving the rainfall, noticeably reduce floods and increase continuous flow in streams flowing out of them. These are results of observations mostly in Western countries and as such are only of general application. It is the quantitative determination of the cost and efficiency of each factor in retaining the water and soil, and spreading out the flow of water that falls in seasonal rains that will largely govern the economics of the type of forest cover that should be created. The basic problems of forestry are adequate maintenance of protective forests and the proper working of productive forests which besides yielding the necessary materials and the revenue continue to protect the soil. To successfully moderate the rights of the local people as against the interests of the distant ones whose lives down the valley are affected by the success or failure of the forests in the upper catchments, to prevent the demands of the present over-riding the needs of the future are difficult problems. To strike the right balance in these matters is not a very easy task.

Extensive cutting, wide-spread burning particularly of ground cover, uncontrolled grazing by domesticated cattle, sheep and goats and the destruction of some wild game leading to disequilibrium in the natural balance of fauna and, therefore, of flora are the usual problems. A continuous increase of population. the diminution of areas under forests in the more populated parts of areas like India and China have led to a vicious circle of progressively acute shortage of timber, fuel, grazing and of course protective forest. It is not easy to set the clock back. But an early realisation of the advanced stage of the disease will be of some help. Afforestation is a comparatively heavy investment from which returns come in small doses and after long periods and as such is a poor competitor for funds. Where, however, the water retarding and soil conserving virtues of protective forests can have a direct effect on the heavior investments lower down in the river valley, the chances of securing adequate funds for such afforestation are distinctly improved. Watershed development as a whole is, therefore, of vital importance to forestry.

Seasonal rainfall over large areas renders more acute the problems of grass lands, groaning already under the burden of large cattle populations and the absence of controlled grazing. While a few of the countries in Asia which are comparatively less populated have abundant resources in land under forests and grass, in the populated areas of India the grass land problem is acute. Parts of the State of Bihar for instance carry a population of as much as 500 cattle and a thousand people to a square mile of land. Almost all the area cultivable has been cultivated and what little grass grows on the infertile areas during the rains is set upon and devoured by hungry cattle and eaten down to the roots. For a period of about six months the land lies barren. As fertility conditions deteriorate, grasses lower down the ecological scale predominate. Under-sized famished cattle that survive on this hazardous but free ration and manage to produce diminutive off-spring that can be made into bullocks, and small quantities of manure for fuel drive out better cattle in whose economics feeding is a large item on the debit side. The change of outlook from one of "more there are the more survive" to one of "fewer and better" in an undeveloped economy is most urgent in relating to grass land policy in the densely populated areas of Asia. The survey of ecological types of grass, introduction through import or breeding of grasses that can survive on lower levels of moisture and have better grazing capacity and practical and economic methods of controlled grazing are urgent needs of grass lands. The supplementing of the grass by tree fodder, and fodder crops, and a persistent positive animal husbandry programme which ultimately leads to fewer and better cattle constitute the long term needs.

Agricultural problems in relation to a watershed are legion. The basic attempt is to secure a higher level of agriculture which would provide not merely a larger and more economic return from the use of land but will utilise the moisture more efficiently and serve as an effective agent of soil and water conservation. Wasteful methods of shifting cultivation raises problems not merely of difficult economics but of obstinate social mores and traditions. Persistent long term education, satisfying economic substitutes and compulsory planting of replacement trees along with the crops seem to offer the only way out. In areas of high population agriculture is often the only way of living open to the majority and where holdings are badly sub-divided and fragmented, voluntary consolidation or with the sanction of law has proved very effective in many States in India where the total holding still is likely to give some return. Intensive use of land particularly with the help of irrigation is the the key to substantial increase of available food supplies per capital in 1951 is estimated at 1640 calories in India against 3180 in the U.S.A. The intensity of levels of production even in agricultural countries vary widely. The effect of adequate moisture and intensive cultivation is reflected by the fact that Egypt with ·28 acre of cultivated land per head of population supplies an intake of 2340 calories aginst India's .83 acre that supplies 1640 calories per head. Cooperative methods of greater agricultural production offer some scope. Industrialisation particularly on the large scale with modern automatic production offers little scope for employment and yet large numbers need to be shifted from agriculture if economic holdings are to prevail. The need for a positive support of of viable small scale industries with larger employment potential is urgent.

The preliminary requisites for effective watershed development are external peace and internal order, an accepted national policy of development of watersheds, adequate staff of technicians and extension servicemen, enlightened leadership of the people

and the willing participation of the people in the educative process of self help. Given this background legislation and regulation for restricting the individual rights in the interest of the public good can and will work and are necessary. Such regulation or legislation and their purposes should be understood all round. Where a rivershed passes through two or more independent countries treaty rights can only cover the basic uses of rights to quantities of water etc. Common programmes will be difficult to secure but where two federating States of the same country share a catchment of a common rivershed, greater co-ordination is possible through the services of the Federal Government. Even inside the State local areas of administration may have varying laws and practices of land management or Local Self Government. The ultimate units of extension service will be much smaller areas dealing directly within concrete programmes. These units will have to know their allotted task and share in the benefit of the watershed development as a whole and act as the last link with the people.

The form of administration of watershed development has varied from case to case. At one end is the separate autonomous administrative control of the watershed as a whole as in the T. V. A. responsible for the policy, programming and execution and directly contacting the farmers on the land. The second form is a Control Policy of State Governments concerned who lay down the policy, the administrative organisation in charge of the watershed being responsible solely for execution and not for policy. This organisation again executes larger projects through direct staff but for all other purposes of extension with the people operates through the existing extension agencies. A third form of administration is for the heads of the different branches of forestry, irrigation, agriculture, etc. to operate separately down the vertical lines of responsibility through their own staff on the ground with no co-ordination at horizontal levels of differing responsibility. Forms of Government and the relationship between individuals and Government vary greatly from country to country and it is rather difficult to suggest a form of administration that will fit in with the different concepts of state craft prevailing in Asia. By and large co-ordination of different functions at different horizontal levels either through the administrative or political hierarchies seems essential as difficult problems of technology, social relations with the people and inter-connected economics arise. While it is necessary that there should be a group of persons charged with the task of translating a policy of inter-connected overall development into execution and solving the day to day problems, whether such a body of persons should be subject to Goverment in regard to policy making or should have the power themselves would depend on the availability of suitable personnel and the willingness of Governments effectively to delegate such powers. While problems of considerable technological magnitude could well be taken up by specially trained staff, it is clear that the smaller soil conserving and water retardation practices on the bulk of the land will have to be done through the people owing or occupying it. Where there is a well developed system of national extension service that service would seem to be the best agency for getting programmes to the ground with the people with whom they are familiar. The national extension service form of administration and the community development programme that is now being introduced in this country is likely to be of the greatest use in watershed management.

The Asian problems are largely those of undeveloped economy. Poverty, illiteracy and poor health are the characteristics, but the new wave of nationalist independence which is passing over this continent has evoked great enthusiasm for self help. By and large the one resource available on a large scale is the man power grossly under-employed on seasonal agriculture. This man power if educated and canalised can serve as pretty effective substitutes of financial resources. That it is possible to secure this through an educative process of self help and programmes that attract the enlightened self interest of the people has been adequately shown. Work on the Yellow river in China and the Kosi and Gandak in the part of India are examples. It is a difficult programme to carry through, requiring considerable faith, skill and persistence. The experience of the last few years has proved that such education is possible and can progress much faster than what any one would have thought it possible a few years ago.

The problems of a watershed are many. Social, economic and political problems arise ; also the problem of the education of the people of an entire watershed on their inter-dependence in the use of the two basic assets of nature, namely land and water. With increasing population, industrialisation and higher consumption the shortage of total assets in land are already obvious in many countries and the shortage of water is becoming more apparent. The earlier coordinated development is achieved, the greater the chance of not merely better utilisation but also the postponement of the date of total shortage. The challenge of our water sheds is a challenge to our fundamental problems of food and drink and the evolution of satisfactory social and economic patterns of our living. To the extent this challenge is understood and met effectively, better living is secured for men, women and children not only in the present but also in the future.

(By courtesy of the Development Centre on Watershed Management for Asia and the Far East, organised by the F.A.O. at Hazaribagh, India).

The Story of the Chainat Dam

By M. L. XUJATI KAMBHU
Director-General, Royal Irrigation Department, Thailand

The last day of the first week in February was a big day for Thailand. For the livelihood of the people of Thailand, and for Thai economy, rice is the most important commodity. And for the growing of rice nothing as important has happended in Thailand for a long time as the completion of the Chainat Dam now officially declared open by His Majesty King Pumipon. It was a festive and impressive ceremony that brought the King, the Prime Minister and many cabinet ministers, the diplomatic crops, and many other dignitaries to the site of the new dam, in the heart of Thailand's Central Plain, some 100 miles to the north of Bangkok. With the building of the dam only part of an ambitious project is accomplished. The Dam, some 6 km downstream of the town of Chainat, is a barrage of reinforced concerete, 305 m long. Heading up 11m of water from the river bed for irrigation and navigation, it is the centre piece in a huge network of canals, large and small, extending over an area of two and a quarter million acres, about the size of Cyprus. Already one third of this network of irrigation canals is finished and the rest will be completed by 1959. With a steady and sufficient water supply from the Chainat Dam, the farmer in Thailand's Central Plain should be able to increase the yield of his paddy fields by about half. Where often there was hardly enough water for one crop, double-cropping will now become possible, with production branching out into new fields of cultivation, such as corn, peanuts, vegetables, etc. Ant while from time immemorial the river called the Menam Chao Phya or the "Mother of Rivers" was navigable only during the rainy season, there will now be year-round navigation. This is achieved by turning two minor rivers and a canal into main supply canal. The year-round navigation will allow the farmer to send his rice downstream at any time of the year and avoid financial losses caused by delays in transport. The regularity in river transport will also revolutionize supply conditions in those parts of the Central Plain where for centuries the water course has provided the only means of communication and transport.

As you drive north from Bangkok to Chainat, you see a country that is flat like a table and rice fields that stretch from one end of the horizon to the other. Here in the Central Plain the land is green, beautifully green, almost all the year round. And the soil is as rich and fertile as rice soil anywhere in the world. Canals criss-cross the huge expanse of rice fields and water seems to abound in and around the fields. The weather seems ideal for rich cultivation. However, appearances are deceptive. Widely variable water supplies have produced a wide variety in harvests and crop risks have been considerable. In fact, over the past 100 years or so the farmers in the Central Plain have had an optimal supply of water only every other year, while for the rest the fields sufferred from either water excess or water shortage. Now, water from the Chainat Dam will supplement insufficient rainfall and water required for the paddy fields will be on tap, so to speak.

Rice is Thaland's main livelihood. It is the major source of income for its population, it provides the largest single revenue for the Government, and most of Thailand's export earnings are derived from rice.

An aerial view of the dam on the right hand side and the causeway on the left hand side, showing how the original flow of the river was blocked by the causeway and a new river bed dug to direct the river into a straight line

Partial view of the dam under construction

Another view of the dam under construction

But despite Thiland's heavy dependence on rice, productivity of Thai rice fields is low—only one third of what a paddy field yields in Japan. Moreover, in future years, less rice will be available for export, for more rice will be consumed at home as Thailand's own population increases and living standards go up. Fifty years ago Thailand, per head of the population, exported some 100 kg of rice while it exports only 60kg now. To put a stop to this declining trend in rice productivity and exports will be one of the major effects of the Chainat Dam. The Chainat Dam will enable Thailand to maintain its position as one of the largest rice exporting countries in southeast Asia. With the Dam and the surrounding canals in full operation, in about two years' time, yields, halved in the last 50 years, should recover considerably. And an additional half a million tons of rice should become available for export, therby increasing the present export volume by one third and bringing back rice exports per capita to where they were fifty years ago.

Higher yields, resulting from better irrigation and improved strains, will give the Thai farmer an effective insurance against slumps on the world rice market ; and double-cropping, facilitating diversification of production will improve still further the economy of Thai agriculture.

The origins of the Chainat Dam go back to the beginning of this century and the rule of King Chulalongkorn. The King had been impressed by modern irrigation works abroad and on returning home from a world trip engaged a Dutch engineer from Java, whom he asked to investigate irrigation possiblities in Thailand. The Dutch engineer after a three-year survey recommended as the most promising project construction of a dam across the river Chao Phya at a place near Chainat.

Plans for the Chainat Dam were revived when in 1912 under the rule of King Vajiravudh, Chulalongkorn's son, a severe drought had a catastrophic effect on rice production. The original Dutch design was confirmed by an experienced British irrigation engineer, brought over from the Punjab. No money, however, was available to put the plans into effect. The project remained dormant until just before World War II, when the Government, anxious to strengthen Thai economy, instructed the Irrigation Department to begin simultaneously with the preparation of designs and the choice of the site. Work on the designs proceeded during the war but once again lack of finance prevented execution of the plan, despite the crying need for rice felt in many countries outside Thailand during the war.

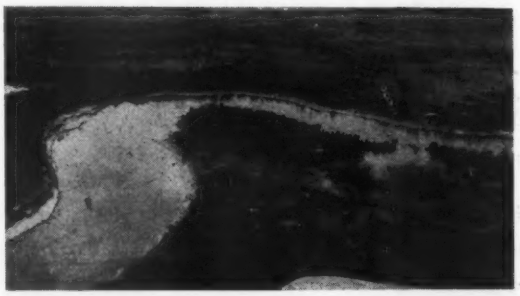
After the war the Thai Government energetically pushed ahead with the project and sought international assistance. An agricultural and economic mission of the Food and Agriculture Organisation of the United Nations visited Thailand in 1948 and strongly recommended construction of the Chainat Dam.

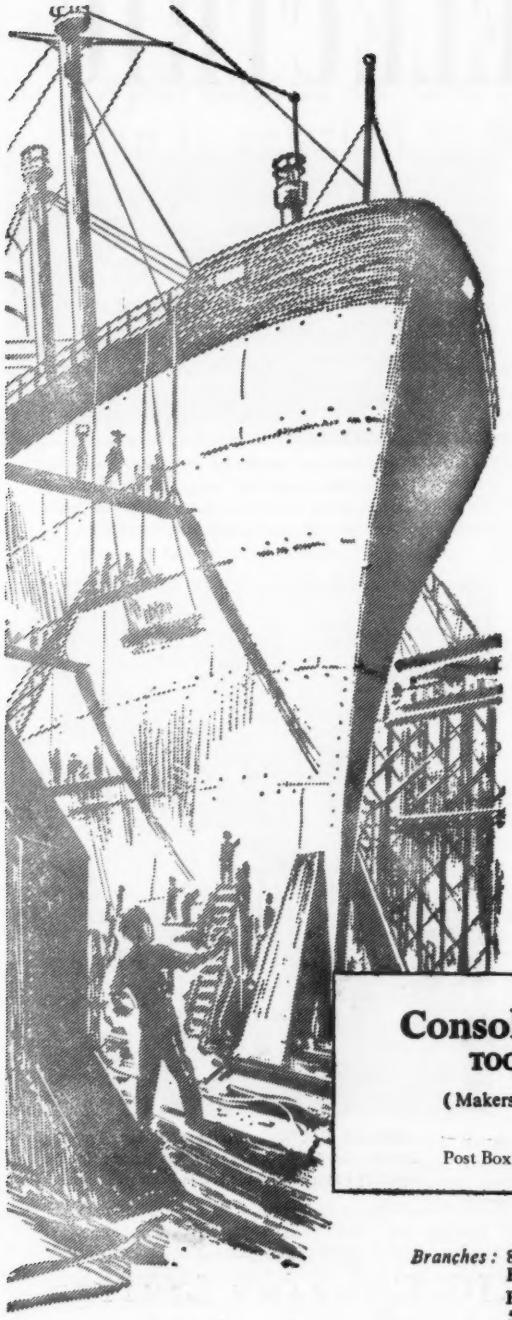
In 1949 Thailand joined the International Bank for for Reconstruction and Development, another of the specialised agencies of the United Nations. In 1950 Thailand approached the World Bank for a loan for the Chainat Dam, and one year later, a loan of $18 million was approved by the World Bank. Throughout 1951 arrangements were made for the purchase of equipment and work on the site began in 1952, but the Korean war caused initial delays in delivery and operations did not get into full swing until 1953. A British firm was contracted to send some civil engineers to the work as co-supervisors and two engineers of the U.S. Department of Reclamation also assisted in detailed designs. An engineer of ECAFE's Bureau of Flood Control and Water Resources Development helped in model testing in the Department's hydraulic laboratory. As a result of these tests four per cent of cost could be saved.

The Chainat dam with the adjoining network of canals is the largest public works project undertaken by the Thai Government. Total cost is about $58 million, with the Thai Government financing all the local outlay for labour and material, while the 20-year World Bank loan of $18 million was used almost exclusively for the purchase of equipment and some material abroad. Cost of the dam alone was about $7 million.

The original plans for the Chainat Dam also envisaged a 30,000 kW hydro-electric power station, but this project was postponed for the time being, as the Government decided to construct another large multipurpose dam at Yanhee, some 150 miles to the north of Chainat, providing for power generation of 560,000 kW.

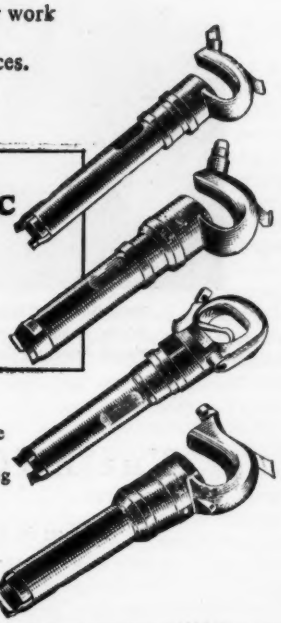
An aerial view showing the original layout of the river





Perfect rivet closing—with CP RIVETTING HAMMERS

For right impact and fine control CP precision-made aero hammers are outstanding. No work-hardening. No injury to the adjacent plate. Three types of handle: offset, push button, pistol grip . . . for work in the most awkward places.



Consolidated Pneumatic
TOOL COMPANY LIMITED

(Makers of Highclass Rock Drills, Air Compressors & Power Tools.)

Post Box 205, Bombay-1. Phone : 242447

Branches : 88, Stephen House, 4, Dalhousie Square East, Post Box 805, Calcutta-1.
Finance House, Pattulos Road, Post Bag 5251, Madras-2.
Post Box 4763, Karachi.
Post Box 185, Lahore.

New Delhi Office : 8A/29, Western Extension Area, Karol Bagh, New Delhi-5.

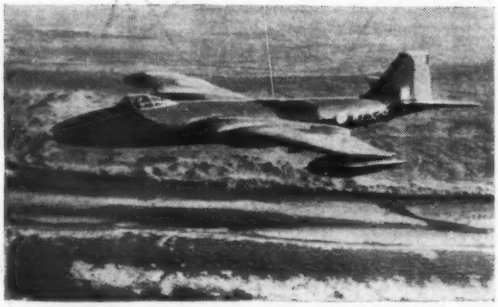
CPT.56.6A

'ENGLISH ELECTRIC'

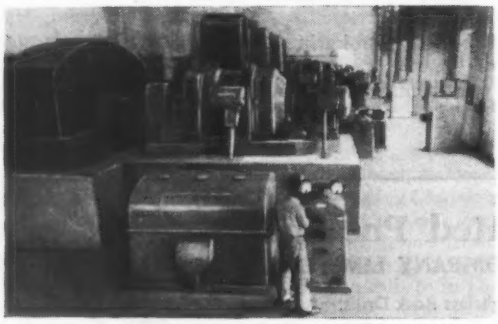
TAKES PART IN INDIA'S DEVELOPMENT

For India, the 'English Electric' Group of Companies have built or are manufacturing a great range of equipment including :

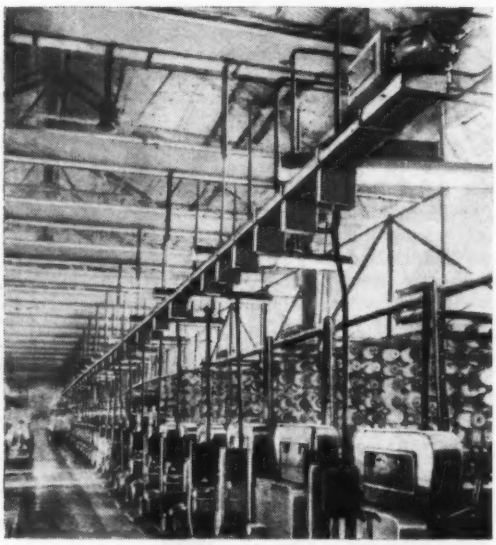
- 'English Electric' CANBERRA jet bombers.
- Steam locomotives.
- Electric locomotives—including electrical equipment and mechanical parts.
- Electric equipment for multiple unit trains.
- Napier 'Deltic' diesel engines for marine propulsion.
- Electrical generating plant including steam, hydro or diesel prime movers.
- Transformers of all ratings including the largest and the first three phase 220,000 volt transformers for India.
- Air break, oil immersed and air blast switchgear.
- Many thousands of horsepower of electrical drives for steel, jute and cotton mills etc.
- Marconi radar, communication and broadcasting equipment.



'English Electric' CANBERRA jet bombers are being built for the Indian Air Force. CANBERRAS are also in service in Britain, Australia, United States of America, France, Venezuela, Ecuador and Peru.



'ENGLISH ELECTRIC' 800 H.P., 3.3 kV Motors driving Cement Mill at the Shahabad Works of Messrs. Associated Cement Company.



'ENGLISH ELECTRIC' Overhead Busbar Trunking System distributing power to the Looms in the Spinning Room of a Textile Mill in Bombay.

THE ENGLISH ELECTRIC COMPANY LIMITED

(Incorporated in England. Liability of Members Limited)

Partners in Progress with Vulcan Foundry, Robert Stephenson & Hawthorne, Napier's and Marconi's

Members of the English Electric Group.

NEW DELHI CALCUTTA BOMBAY MADRAS LUCKNOW

EEC-37A

Experiences of the First Five-Year Plan in relation to Irrigation and Power Projects

By P. P. AGARWAL, I.C.S.
Planning Commissison, Government of India

The first five-year plan was intended as a step towards the promotion of rapid and balanced economic development. The programme of development of water and power resources, attempted after a comprehensive review of the needs of the various regions of the country was calculated to strengthen the economy by promoting industrial development and bringing more area under plough thereby increasing food production. The Plan has shown fair results in this respect and has evoked public cooperation and enthusiasm, thus giving a new trend to current thinking and policy.

Power, from whatever sources it is obtained, is the life-blood of the economy of a country. The standard of living of a people is judged by per capita consumption of electricity and by this standard our country is very much lower in the scale. The per capita production in India at the end of the First Plan is only 30 units as compared to 3,310 of U.S.A., 850 of U.S.S.R., 711 of Japan and 60 of Turkey. The development of power requirements was, therefore, given a high priority in the First Plan. Out of the total investment of Rs. 2,356 crores in the First Plan a sum of Rs. 260 crores was earmarked for power development projects and the proportionate cost of multi-purpose schemes. It was proposed to increase the total installed capacity in the country from 2.3 million kWh to 3.6 million kWh during the plan period. Against this target of 1.3 million kW, the actual addition achieved was 1.1. million kW. So, this is a fairly good progress considering that the first plan was expected to lay the foundations of planned economy rather than achieve spectacular results. The total area under irrigation in the country has increased from 51 million acres to 67 million acres over the first plan period. An additional of 21 million acres is expected to come under plough by the end of the second plan with the result that irrigated area in the country will increase by 75 per cent in ten years. However, we cannot be smug about the achievements of the first plan in the irrigation and power field as the task before us is stupendous and does not brook any slackness.

It, therefore, becomes our foremost task to assess and evaluate the experiences gained in the execution of the various projects in the first plan. What is it that obstructed us in achieving our targets or even exceeding them ? What changes in the procedure or way of doing things should be made to facilitate the execution of projects in order to obtain the maximum benefits in a reasonable time and at a reasonable cost. Broadly speaking, the following factors have been found, by experience, to hamper the progress of our projects :—

(1) Shortage of qualified and experienced technical personnel ;
(2) Inadequate statistical data ;
(3) Absence of maintenance of proper record regarding experience and knowledge gained in the execution of large projects ;
(4) Lack of proper coordination ;
(5) Lack of proper phasing of the construction programme ;
(6) Unnecessarily protracted procedure involved in complying with obsolete account rules and regulations not applicable to present day conditions ;
(7) Lack of adequate administrative supervision over the progress of construction programme ;
(8) Lack of public cooperation.

The shortage of qualified and experienced technical personnel has been felt all along during the first plan but very little has been done to overcome this difficulty by initiating practical training programmes for persons qualifying from technical institutions in the country. It has been observed that there is not so much shortage of qualified personnel as that of persons with experience required for initiation, designing and execution of large projects. The fresh technical graduates face the inevitable question from the employers about their practical training and experience which they are invariably lacking. The employers and specially the Government which is the biggest employer of technical personnel should view this situation sympathetically, because unless these graduates are given an opportunity to work on the actual design or construction of projects they are bound to remain inexperienced engineers. If young engineers are associated right from the beginning with engineers actually engaged in the execution of large projects, a substantial cadre of experienced technical personnel will be ready within a span of a few years. Care could also be taken while ordering plant and machinery from abroad to insert a clause in the purchase agreements that the manufacturers will train certain number of young engineers from our country in their works and associate them with every process from the manufacture of the plant upto its installation. Young engineers could thus be trained not only in manufacturing process but also with the work relating to erection of plant at site. It

will be in the national interest to keep such trainees in the regular employ of the Government as this would ensure their retention in service after their training is over.

The prime requisite for proper planning, design and implementation of river valley projects is the availability of essential data. Long-term chronological data is necessary for selecting the important suitable sites and designing a hydro-electric project. A number of projects executed under the first plan were started without completing proper investigations resulting in subsequent changes in their design and scope. This should be avoided by setting up proper organisation at the Centre and in the States for carrying out investigations at suitable sites all over the country. It has been observed that while preparing estimates for certain projects realistic rates were not adopted. This necessitated further revision of rates while the execution of projects was in progress. This practice results from non-availability of essential information. A consolidated data on the rates and costs regarding projects already completed will be of great help in this regard.

An integrated power system, which can only be developed by planning for most effective and balanced utilisation of the country's resources makes possible for the full economic exploitation of each power site at the lowest practicable cost. For realising the optimum benefit from the coordinated operation of power generation resources and to effect an economy in capital expenditure and production expenses, it is necessary to co-relate the generating capacity with the anticipated demand in an area over a period of years and for this purpose an advance blueprint is necessary. An assessment of a prospective load in the region proposed to be served by a power project is also essential for correct phasing of its construction programme. So far, load surveys have been carried out in this country for particular regions only to collect data for certain projects. But what is called for is a coordinated effort on the part of the Centre and the States to carry out a systematic load survey all over the country. During the past few years the rate of utilisation of power has been more rapid than before. It is likely to rise during the second plan. In areas served by projects such as the Bhakra-Nangal, Hirakud, D.V.C. and the grid systems of Andhra Pradesh, Bombay, Madras, Uttar Pradesh and Mysore, the old prospects have far exceeded previous anticipations. The gradual lifting of restrictions on power supply in various parts of the country has been, to some extent, responsible for increased demands. But even more than this are the effects of the economic development during the first plan. The present estimate of loads for the next ten years will have to be revised upwards. The Ministry of I & P have probably taken up this survey on a national basis and field data are being collected through four regional centres. But what requires to be emphasised here is that the survey should be a continuous process so that every region in the country is covered at least after every five years. This would provide sufficient up-to date statistical data to the planners and engineers for designing future power projects.

The importance of maintaining proper record of experience and knowledge gained in the execution of a project is not being fully appreciated at present. It should be the foremost duty of the engineers in charge of execution of projects to preserve a complete record in this respect. This would facilitate planning, design and execution of future projects, as the engineers who were not actually engaged in the execution of the projects already completed would have the benefit of utilising the knowledge and experience gained on them in the execution of new schemes.

For the achievement of optimum benefits development schemes of different States have to be closely coordinated. Water stored in the reservoirs in one State may be used with advantage for irrigation and power generation in the adjoining state. Similarly, power available in one State may be distributed in other States. In certain cases, it may be necessary to divert waters from one basin to the other for the benefit of the region as a whole. Cooperation between the States is, therefore, essential for investigations, load surveys, allocatian of waters and power generated and sharing of their costs. The Government of India have recently passed two Acts, viz. the River Boards Act, 1956, and the Inter-State Water Disputes Act, 1956 ; the first Act enables the Central Government to consistute Boards for different inter-State rivers and river valleys in consultation with the State Governments concerned for preparing schemes, allocating their costs and benefits and coordinating the activities of State organisations, etc. The second Act provides for the constitution of Tribunals with necessary authority for adjudication of disputes between two or more States in respect of development of inter-State rivers and river valley schemes.

Coordination between various branches of the organisation executing a project is also very essential. It is understood in certain cases that the dam was complete but the power station or the canals were not ready to utilise the waters stored or else if the power station was ready, the transmission lines to carry the power for utilisation were still under construction. In some cases when both the power stations and the transmission lines were completed, the tube-wells, pumping stations or the factories were not ready to utilise that power.

The proper phasing of power projects and their execution should be carefully arranged to yield maximum benefits and financial returns from investment at each stage. Invariably, it is possible through proper organisation and planning to obtain larger benefits from the expenditure incurred. To obtain maximum results, benefits should accrue at each stage and there should be no time lag between the availability of benefits and their utilisation. Steps should be taken to prepare the people for using electricity and they should be guided and assisted in its scientific use so that the maximum increase in production can be realised. In this respect, the Community Projects and the National Extension Movement have an important role to play and should be utilised from the start for ensuring that the demand for power and also the arrangements for its use are ready as soon as it is supplied.

Our Public Works Account rules that were framed about a century ago were obviously intended for works very much different in type and magnitude from what are being undertaken these days. There are rules which could seldom be strictly followed even in those days when the number of major works was very small. But now when the number of works and

their magnitude is much bigger, compliance with these rules is almost impossible, with the result that on every project the engineers in charge have to take the blame for breach of these financial rules. Still there is a class of rules compliance with which obstructs the smooth and rapid progress of work. A lot of time can be saved and adverse and uncalled for criticism avoided if these rules are modified to suit the present day condition. Simple account rules which can be observed and complied with are better than the so-called perfect rules which cannot be followed in practice and merely cause confusion ; non-compliance with them is detected at a time when it is too late to mend matters.

There is a general complaint about infructous expenditure during the execution of projects. The insufficiency of accounts-staff trained in public works accounts is also one of the main reasons for the non-compliance of accounts rules. While planning for large projects, the requirements of accounts-personnel should be considered together with the requirements of technical personnel. The execution of projects will be greatly facilitated if accounts officers beside their training in public works accounts have also some technical background so that they are able to appreciate the difficulties and view points of engineers while examining the estimates and accounts of the expenditure incurred. It will not be out of place to suggest that if the accounts-officers visit the sites of the projects now and then to observe the actual execution in progress, many of the time-consuming observations and flimsy objections that are raised by them merely because of their inability to see beyond the files will be avoided. The training of accounts personnel should be considered at par with the training of technical personnel required for the projects.

A word must be said about the desirability of exercising adequate administrative control over the execution of projects and the work of coordination and survey being carried out by various agencies with a view to ensuring that there is no slackness in progress due to any cause. For this purpose it seems desirable to set up some inspection units in the Ministry of Irrigation and Power, who should visit the various projects at regular intervals and submit their reports on the progress made therein to the Central and State Governments. In this connection it may be stated that the figures relating to electric consumption in India indicate that only 5% of the energy generated in the country is consumed in rural areas. Rural electrification had been neglected in the past because it is not a financially attractive proposition, and private enterprise was largely responsible for development of electric power supply. The first plan did not provide for any amount separately for rural electrification ; some villages were electrified in pursuance of the general plan for electrical development and the scheme for expansion for power facilities for increasing employment opportunities. The number of villages electrified at the commencement of the first plan was 2,931 and it stood at 6,500 at the end of the Plan period. The Plan provides for incurring an expenditure of Rs. 75 crores on rural electrification ; about 10,000 new small towns and villages are expected to receive supply. Since rural electrification would be conducive to raising the standard of living of the masses, it is extremely desirable to pursue the programme of extending electricity supply to villages more vigorously than has been possible heretofore. The State Governments should be given some inducement to take up the schemes, in the form of subsidies and should be further helped in preparing long term plans for the purpose. The Central Government could also undertake the preparation of economic and suitable designs for the standardisation and construction of rural substations and lines. It is understood that this work is being undertaken by the Central Water and Power Commission but it has not made any headway so far. This would appear to suggest the need for a closer eye on this work and other important works by the Administrative Ministry concerned.

For the successful completion of projects and reducing their cost a large measure of public cooperation is of fundamental importance. The average citizen is able to appreciate vividly and to contribute actively to work that lies near him or touches his life and well-being intimately. It is suggested that works requiring unskilled labour should be entirely entrusted to the villagers and not to the contractors. This will greatly benefit the economy of the near-by villages and would also result in cooperation among villagers in other spheres as well. The success of public cooperation in the Kosi Project has shown the way for further efforts in this direction. Nevertheless, these instances of people's participation and the results obtained there from in particular areas reveal the great possibilities of this system. The assistance of voluntary organisations should be obtained to evoke public cooperation for the implementation of the Plan. The right type of publicity and propaganda will be of great help in obtaining the cooperation of the people.

Mention should also be made of the important role the rural cooperative societies can play in the implementation of the Rural Electrification Programme. First of all the Cooperative Organisation in a Community can assist the load survey party in collecting the relevant information. It can represent the community for signing the collective agreement with the power supply undertaking for obtaining the supply for the community and in its turn can sign agreements with individual consumers. It can make available to the consumers the electrical appliances meant for processing of agricultural products on hire purchase basis and train the people in their proper and scientific use. The cooperatives can help in seeking markets for the products of the small-scale and cottage industries coming up in the community due to electrification. At a later stage they can actually handle the sale of such products. They can also formulate a programme of training in the maintenance and repairs of electrical appliances and transmission and distribution lines in the village. The trainees could be recruited from among the members of the community. When sufficient number of persons have been trained, the Cooperative Organisation can take over the maintenance work of the distribution lines in the village from the power supply undertaking. At the same time the villagers will not have to seek assistance from outside agencies for carrying out simple repairs to their electrical equipment. Incidentally, this arrangement would also relieve unemployment in the rural areas to a certain extent.

Correct and apt application of lessons learnt while implementing the first plan will ensure the fulfilment of the second plan.

(*A Paper read at the Engineers Seminar held at Hirakud in Jan.* 1957.)

Some Problems on the Design and Construction of Earth Dams—II

By RAUL J. MARSAL and ENRIQUE TAMEZ G.

Concluded from March issue

(f) Compressibility

The compressibility of compacted materials selected for construction of impervious cores is generally low. Nevertheless, for some soils like the clay of Presidente Aleman Dam, the properties of which are shown in fig. 5c, confined compression tests are required to determine the corresponding coefficients of compressibility and consolidation. It is convenient to perform such tests on two specimens having the optimum void ratio given by the Proctor test, but one of them with optimum moisture and the other one saturated. Sometimes, both tests are combined into one ; this is accomplished by compressing a specimen having optimum conditions under a certain pressure, then the specimen is allowed to saturate and the load is increased afterwards in the usual manner.

For most of the soils tested at the Laboratory, the "time-deformation" curves fall apart from the classic consolidation curve (9) even when the degree of saturation is close to 100%. Deformation is rather a logarithmic function of time.

In estimating the probable settlement of the impervious core, the expression proposed by G. Gilboy (10)) can be used. Also, the Newmark's formula (11) can be applied to compute the approximate values of the stresses caused by the weight of the overlaying materials.

Settlement computations are particularly important when the abutments present abrupt changes of slope, because of the possibility of cracks in the impervious core due to differential settlements.

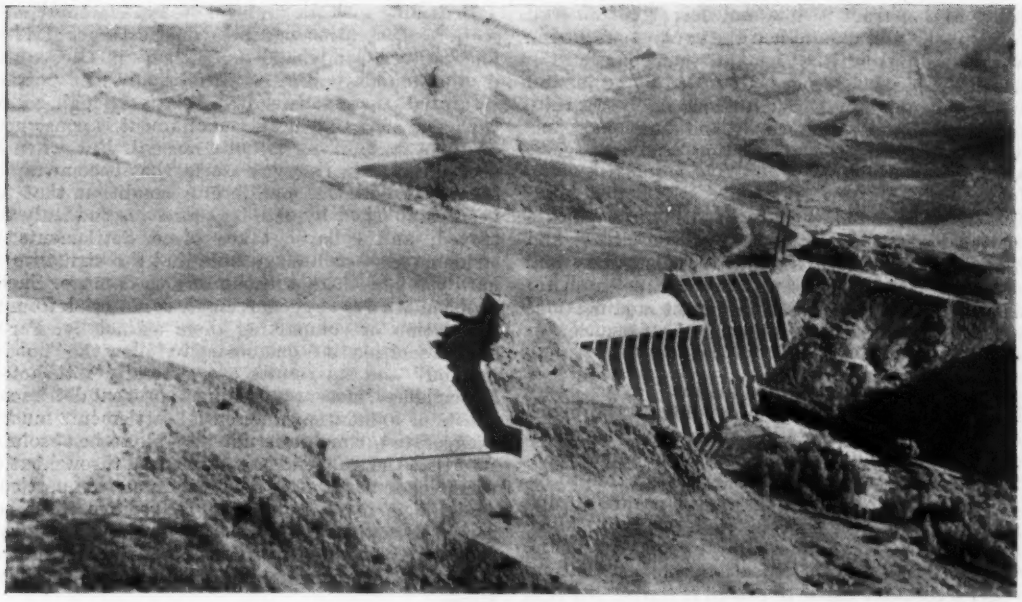
In the dams constructed by the SRH, the maximum settlements of the crest vary from 0.5 to 2% of the height, and cracks have been observed in some of them. This problem will be treated in detail under section (j).

(g) Permeability

Except for a few cases, as in Sanalona Dam, the permeability of campacted core materials varies from 10^{-4} to 10^{-8} cm/sec. The flow of water through the structure is very small and hardly measurable. Permeability tests are run at the Laboratory by means of constant or variable head permeameters, using representative samples having optimum density and water content (4).

Whenever a dam has to be founded on a permeable formation, field permeability tests have to be conducted, due to erratic condition of natural deposits. The method followed in these cases consists simply in pumping a known discharge of water from a well drilled through the pervious formation and protected by a slotted casing. Once the flow becomes steady, piezometric levels are measured at various points around the well (12). Only as an exception the depleted phreatic surface is symmetrical about the well It is normal that such surface be distorted on account of the effect of irregularities or anisotropy of the formation, as well as the influence of the underground river flow. Fig. 7a shows the level lines of the water surface measured during a field test performed in the foundation of Abelardo L. Rodriguez Dam. In order to estimate the average coefficient of permeability it was necessary to analyze the radial flow towards the well by means of flow nets. Results of the test gave an average value of 1.5×10^{-1} cm/sec. In view of the fact that the depth of the pervious deposit is about 60m at the center of the river channel, it was decided to build the dam on such formation, controlling seepage by means of an impervious blanket of compacted earth, having 6.5 m in average depth and 300m in length, placed on the upstream side and connected with the core (see fig. 1). Electric analogy studies were made to calculate the discharge through the foundation and to know the hydraulic gradients at the seepage outlet. It was concluded that a discharge of $2m^3$/ sec should be expected at full reservoir with a head of 22 m. This condition has occurred twice and the flow measurements made downstream showed that the predictions were correct. (see figure 7b).

Determinations of the permeability coefficient of the sandy conglomerate used in Sanalona Dam were made according to the following precedure: two paraallel vertical faced trenches were excavated in the compacted embankment, leaving an earth prism 1m wide between them. Both trenches were filled up with water, and once the surrounding soil was saturated, a difference in level of the water surface in the trenches was established by pumping, and the corresponding discharge was measured. With this data and the aid of a graphically constructed flow net (figure 7c), a permeability coefficient of 3×10^{-4} cm/sec was obtained. Although this value is relatively high, it is estimated that seepage through the embankment is not larger than 20 l/sec. No seepage is visible at the downstream toe of this dam, but it is probable that it



LAS VIRGENES DAM—A concrete structure with round head buttresses, 190 feet high and 350,000 acre feet capacity, built on the San Pedro river.

is concentrated toward the pervious river deposits.

(h) Embankment Foundation

Due to the uncertainties that always arise with regard to the geological conditions of every formation, the foundation of a dam is carefully studied by means of surface and underground explorations of the site. This phase of the design is very important, since it allows to forsee the troubles that may be encountered during construction, and to make a rational program for an adequate treatment of the foundation.

On this particular, the prevailing criterion of the SRH engineers is that the dam be founded on incompressible material, and that the earth core be carried down to a reasonably impervious rock formation by means of a trench or a cut-off, or a combination of both (see fig. 1, Alvaro Obregon Dam). When dealing with a rock foundation, it is previously treated (grouting) in order to avoid seepage through joints. Nevertheless, some instances were found where it was not economically feasible to attain either of these two conditions due to the geology of the site ; such was the case in Abelardo L. Rodriguez Dam.

According to the geological characteristics of the site it is possible to distinguish two main types of foundation : rigid and compressible. The first one is constituted by rock of variable strength and, frequently, jointed. The second one is composed of layers of material that can be appreciably deformed under the action of loads.

Rigid Foundation

The usual treatment of a rigid foundation is as follows : (1) Surface clean-out to eliminate vegetation, soil, or weathered rock. (2) construction of a concrete cut-off wall or simply a trench filled up with compacted earth, to make the most jointed zone of the foundation impervious (3) cement grouting through the cut-off to form a grout curtain of variable depth, depending on characteristics of the rock. The usual depth is one half of the maximum water head. (4) Surface treatment of the rock in the area underlaying the impervious core, forming a grout blanket.

Excavation for the concrete cut-off is done with the aid of pneumatic equipment or steel wedges, in order to avoid the use of explosives that may damage the rock.

Grouting is carried on by the stage method. The depth and pressure of the various stages are selected according to rock characteristics and the data on water loss reported during geological exploration. The water cement ratio of the grout depends also on rock conditions (13). Generally speaking stage depths vary from 5 to 15 m, grouting presssures from 1 to 3 p.s.i. per meter of depth, and water cement ratios from 0.7 to 6.

Experience of the SRH engineers on this phase of construction is quite varied. The case of Presidente Aleman Dam is extraordinary because of the tremendous volume of grout used. The dam is founded on the anticline of a heavily jointed and cavernous limestone formation. The total consumption of cement was 12,300 tons, giving an average consumption of 350 kg/m length of hole. Up to the present, the maximum head in the reservoir of this dam has been 52 m and no seepage whatsover has appeared on the downstream side. Fractured basalts have been a source of trouble even when they were grouted carefully. In La Vega Dam, for example, after construction of the concerete cut-off and grouting operations on the right abutment, a field test was performed, pumping from a pit excavated on the downstream side of the cut-off and observing the level of the water in other pit, located on the upstream side. The results of this test showed a fairly free communication between both pits, and it was

decided to construct a new and deeper cut-off wall parallel to the first one. When the excavation for the new wall was made, it was found that some of the joints in the basalt had not been sealed by grout and the water could flow through them freely. Granite foundations as those of Mocuzari and Sanalona Dams had moderate cement consumption, and seepage is either none or negligible.

Treatment of foundations by grouting is a delicate operation and requires the skill of specialized and well-trained personnel. Geological explorations and field tests are the basis of an adequate program for each particular problem, but important modifications should always be expected during the execution of the works.

Compressible Foundation

The engineer meets the most difficult problems when thick strata having a low shearing strength and a high compressibility are present in the foundation, and for economical reasons, it is not advisable to remove them. On account of the erratic nature of such formations, it is necessary in such cases to make complete studies of the mechanical properties of the various materials and their stratigraphic distribution. Another important phase of design is the adoption of a simplified soil profile that will make stability and settlement computations easier. It should be pointed out that compacted earth structures are not, in general, very flexible. Although they are able to undergo larger deformations than concrete and masonry structures, they are susceptible to cracking, when the gradient of the differential settlement exceeds a certain limit which depends on the type of soil and its placement moisture. The section of the dam must be designed in such a way that shearing stresses induced in the foundation be compatible with shearing strength of the soil, and at the same time, differential settlements be as small as possible. As a result of these two conditions, dams founded on compressible soils have always very flat slopes, and sometimes wide berms, as in Marte R. Gomez Dam (see figure 1).

In dealing with the problem of "liquefaction" under section (e), attention was called on the danger of having fine, uniform sands, and organic silts in a loose state in the foundation of a structure. When partially saturated, these soils show a relatively high bearing capacity, such that if an embankment is constructed on them its behavior is quite normal. But when the first filling of the reservoir starts, they become rapidly saturated and the equilibrium condition that had been established by capillary forces is suddenly destroyed, and collapse takes place. Settlements are sudden and of such magnitude that the structure can hardly follow them without serious damage. Such a problem is solved by removing these materials from the foundation or compacting them artificially. For the second solution, it is customary to follow the "flooding method" and its results are generally satisfactory. Nevertheless, measures tending to prevent detrimental effects of foundation differential settlements must be exaggerated, since it is not possible to be absolutely sure that the soil conditions are equal throughout the whole loaded area after flooding. In certain particular cases, it is more economical to remove these soils from the foundation and use them again, properly compacted, in the impervious core. Such is the case of Falcon International Dam built across the Bravo River.

(i) Stability of Slopes

Under this section, the methods adopted by the SRH for analyzing the stability of slopes will be briefly treated. Assuming that the failure surface is cylindrical (14) and that it is reasonably acceptable to consider that the sliding portion of the slope behaves as a rigid body (15), (16), the tangential (T_a) and the corresponding normal forces (N_a) acting along a potential sliding surface are calculated. The law of variation of the uplift pressure (U) along the same surface is defined from a flow net analysis, in order to take into account the effect of such pressure on the normal forces (N_a —U). From experimental information the shear resisting forces (T_r) are estimated, and the factor of safety (F_s) is computed as the quotient be-

LAS VIRGENES DAM.—Another view with the spillways working.

tween the algebraic summation of T_r and T_s. Repeating this process for other cylindrical surfaces, the minimum value of F_s is calculated. The factor of safety must be equal to or greater than 1.5, according to SRH criterion.

The upstream slope is analyzed for a drawdown condition, and the downstream one assuming a full reservoir. Flow nets are drawn for both states of stress, following Forcheimer's graphical method.

For impervious cores constructed of cohesive materials, it is assumed in stability analysis that two limiting consolidation degrees can be encountered. (1) The construction period of the dam is relatively short and the degree of consolidation attained by the soil at completion is practically none. It is admitted for this condition that the shearing strength (s) of the core material is represented by the results of triaxial quick tests. Such an assumption takes implicitly into account, the effect of construction pore pressures that may develop. (2) When total consolidation has taken place, the value of (*s*) is that corresponding to consolidated-quick tests. Such values include the effect of pore pressures that may develop during failure as a result of shearing strain.

Other authors prefer to use the so-called effective values of shearing strength in the stability analysis, taking into account the effect of pore pressures developed either during construction or as a result of percolation through the dam body, but not the pore pressure that develops due to the action of shearing stress. This pressure is difficult to evaluate. It is felt that the criterion adopted by the SRH, which has been basically introduced by Dr. Arthur Casagrande, also includes such effects, as it was explained under section (e).

The method of analysis previously described is equally applied to homogeneous earth sections or to those having substantial rock shoulders and a relatively narrow impervious core, except when such core is going to be built from organic silts of the type described under section (e). In such cases, the procedure established by G. Gilboy (10) for analysing haydraulic-fill dams is followed, requiring a factor of safety greater than 1.1

It is convenient to insist, once again, that the most important aspect of slope stability analysis is the correct evaluation of the shearing strength of the materials that constitute the dam.

(j) Cracking of the Impervious Core

In the preceding pages, when dealing with compressible foundations, the possibility of cracking of the dam as a consequence of differential settlements originated in the foundation was mentioned. Earth dams constructed on sites where the abutments present sudden changes in the slope, are also frequently affected by transversal cracks. Such cracks appear wider at the crest and they become narrower with depth. Their magnitude and number depend upon the intensity of the differential movement. It is easy to discover this type of cracks if the crest revetment is removed, and they are dangerous because the water flowing through them may cause intense piping and, consequently, a partial or complete failure.

Fig 8 shows two examples of dams constructed within the same area (Excame and Trujillo), having approximately the same height of 45m. Both dams showed a heavy transversal cracking. It can be seen that these two sites have abrupt changes in the slope of the abutments. Two 5 cm wide transversal cracks were discovered in the crests of the two dams, the cracks becoming narrower with depth until they are 1 mm. wide at 7m below the crest, as it was revealed by open pit explorations. Smaller cracks appeared on both sides of the main ones. It should be noted that Excame Dam has a maximum settlement of 1.20 m and Trujillo 0.60 m only. Nevertheless, the intensity of cracking is practically the same in both structures. This somewhat contradictory fact can be explained comparing the mechanical characteristics of the soils used in the impervious cores (see figure 8). The clay of Excame was able to take more strain than the clayey sand of Trujillo.

Notwithstanding that water has flowed on the spillway crest of Excame and the water surface has been 6 m below the dam crest, no erosion was visible in the cracks. In Trujillo the conditions have been different since water surface has never reached the elevation of the crack bottom. Repairing is being done by opening a trench 2m wide and 8m in depth along the crest center line, proceeding in 5m lengths. After grouting the cracks in the bottom of the trench with a water-clay grout, the trench is back filled with a compacted clayey soil having a water content 3% higher than optimum. Compaction is done with pneumatic tampers. Once the filling operation is completed, a thicker clay grout is injected in the main cracks on both sides of the trench.

A similar type of cracking appears also in the vicinity of the contact between two zones of the dam, when they have been constructed at a different time. Frequently, according to a construction program of the job, a certain area of the river is left open to allow the passage of floods, and constructed quickly afterwards during the dry season. This area, commonly known as the "closure section," at the time of completion is in a different state of consolidation with respect to the sections constructed previously. This is particularly important in clayey soils as those used in Presidente Aleman Dam (figure 5-c), as well as in sandy-silt materials. The latter give very rigid structures susceptible to cracking due to differential settlements. Dr. A. Casagrande in his paper "Notes on the Design of Earth Dams" (17), reports an example of intense and dangerous piping, caused by flow of the water through cracks located along the contact of the closure section with an older portion of a dam. According to his recommendations, the most effective measure to control the flow of water in transversal cracks consists of placing well-designed filters on both slopes of the impervious core. At present, the SRH designs invariably include well-graded filters protected by a transition zone made out of rockfines placed between the filter and the rock shoulder.

(k) Movement of the Rock shoulders

In several of the dams constructed recently, cracks located approximately along the contact of the rock shoulders with the core have been observed. The width of such cracks varies from 2 to 5 cm, and they show a small vertical displacement between the edges,

associated with a slight downward tilting movement of the crest, as shown in fig. 9a.

These cracks have appeared near both the upstream and downstream edges of the crown, and not always simultaneously. Those on the upstream side are associated with a rapid filling of small reservoirs, or an intense rainfall. The latter appear only after a heavy rain. However, in La Soledad Dam, Fig. 9b, compppletely founded on sound rock, a longitudinal crack appeared at the middle of the crest. The shoulders showed the same tilting movement. Open pit excavation disclosed that the crack is limited to the cover of the crest, and it does not affect the core. Observing the deformed section of the dam, shown in Fig. 9-b, it is concluded that the settlements of the shoulders have been greater than those of the impervious core, causing the core to protrude between the rock-fills, and the crack to appear at the center of the crest. It should be remembered that the slope of the shoulders is usually 2 horizontal on 1 vertical, and that the rock is placed by dumping in layers of a thickness varying from 3 to 5m. No water was used when placing the rock in any of the dams that showed this type of cracking. On the other hand, a layer of uncompacted core material is frequently left between the core and the shoulders because, during construction, the earth fill is usually kept at a higher level than rockfill.

It is considered that the facts above mentioned contribute greatly to produce a rearrangement of the rock masses, as a result of rainfall water flowing through their voids. The changes in intergranular pressures caused by flotation during the first filling of the reservoir may explain the movements observed near the upstream slope. Such movements become very important when the structure of the rockfill is very loose.

Although cracks of this type do not endanger the stability of the dam, it is desirable to avoid them. The application of substantial amounts of water in the form of jets is a very efficient means of promoting a better arrangement of the rock fragments in the shoulders. Removing the layer of uncompacted material from the core is also advisable.

In those dams, the shoulders of which are founded on soft strata having a low shearing strength, removing the loose layer of the core may be a fundamental measure. In one of the dykes of Presidente Aleman Dam (see figure 9c) a considerable movement of both rock shoulders was observed after an intense rainfall, when the water in the reservoir was at an elevation lower than the base of the dyke. The cross section after the slide is shown in figure 9-c.

This structure had been designed on the basis of the criterion above explained, and the factor of safety for the assumed cylindrical sliding surfaces, cutting both the core and the foundation clay, was greater than 1.5. During construction, the core was always kept at a level higher than the rockfills, thus resulting in an uncompacted layer of clay on the slope of the core which was not removed before placing the rock fines and rock. The clay used for the core is extraodinarily susceptible to variation of its properties due to changes of water content, and its shearing strength for loose condition and a water content higher than optimum is practically none. Analyzing the stability of the sliding surface indicated in figure 9-c and taking into account the shearing strength of the foundation as well as that of the loose material when becoming saturated by the rain water, a factor of safety smaller than unit was found. Consequently, the rock shoulders were unstable. It is worthwhile noting that two portions of the dyke were founded on limestone which was not covered by the clay deposit, and no movement whatsoever was observed in such portions. Those parts of the dyke founded on clay, but having less than 8m in height did not show signs of movement either. Stability analysis for such parts, making the same assumptions as for the failure areas, gave factors of safety greater than 1.4. This type of movement has not occurred on even higher dams, having sandy materials in the core, which have been constructed with the same procedure.

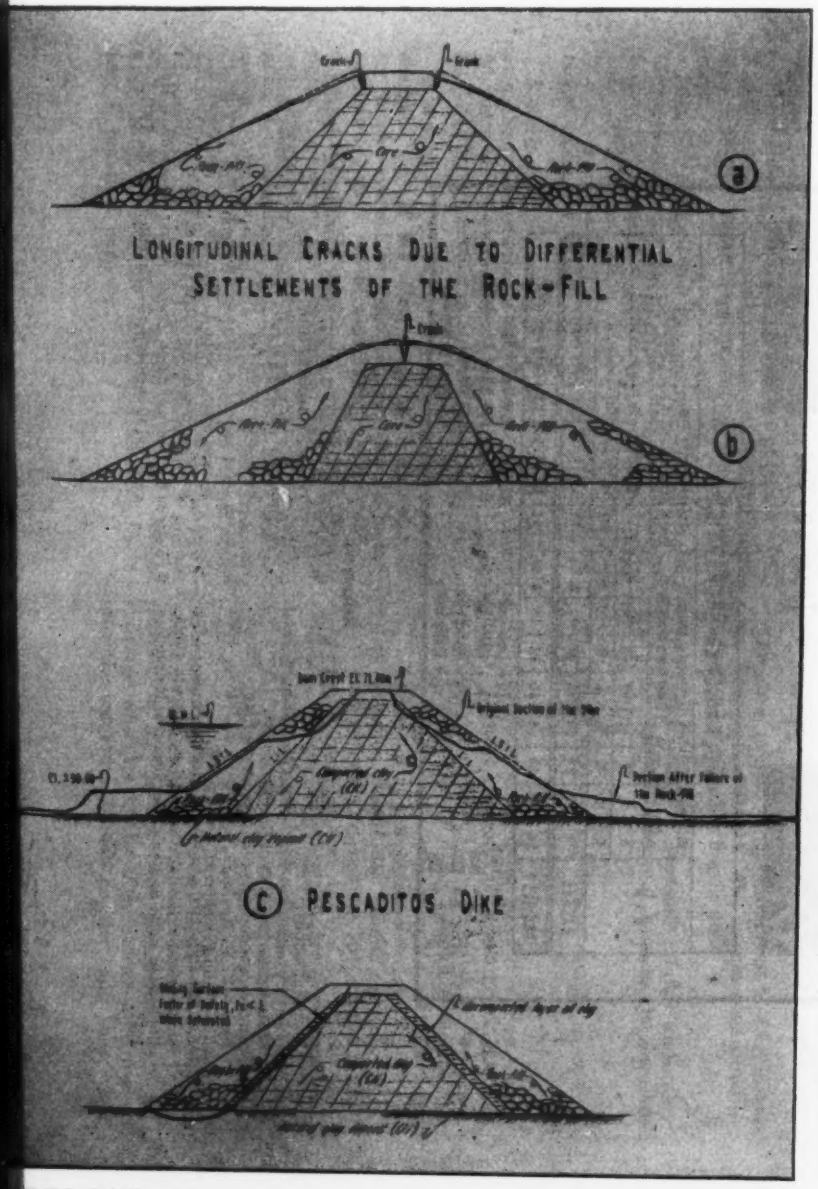
Repairing of the structure consisted of adding a berm, 5m in height and 16m wide at the toe of both slopes. Its behavior has been satisfactory until now, notwithstanding that rainfall in the dyke area has been extraordinary during the year.

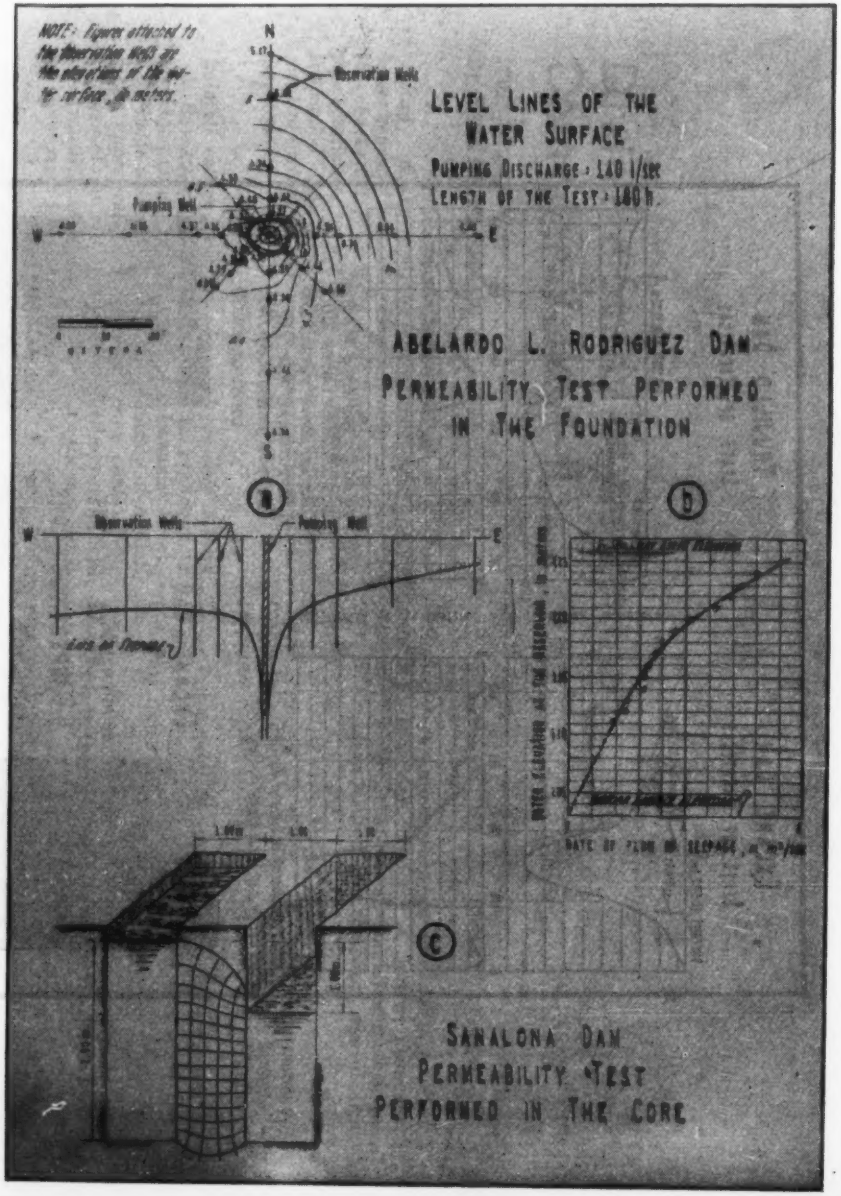
From the preceding example, it is concluded that it is important to compact those layers of the core that are in contact with the rock shoulders, particularly so when the soil used in the core is a clay and the foundation has a low shearing strength. It is necessary to organize construction operations in such a way that compaction equipment be able to pass close to the core slopes. If such condition cannot be achieved, the loose material should be removed from the core before placing the shoulders.

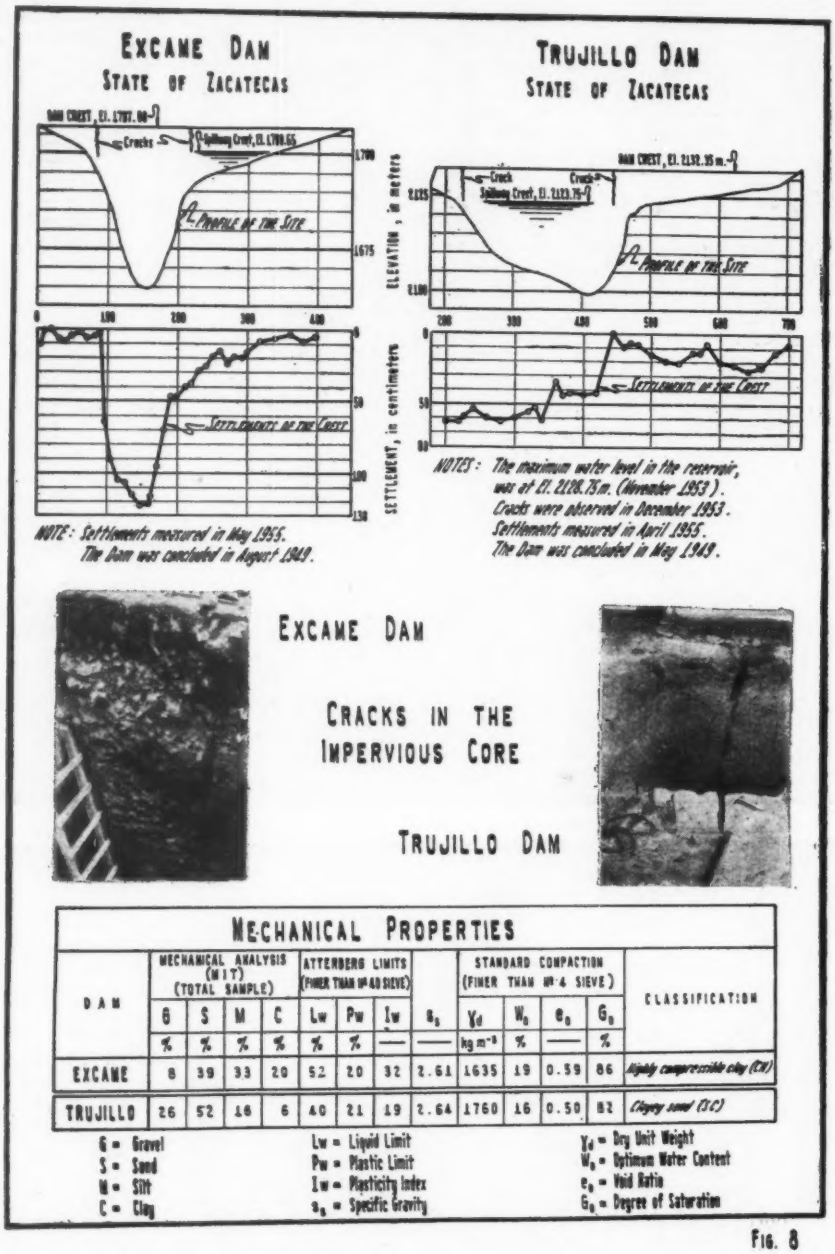
(l) Conclusion

It has been intended to present a brief bird's eye view of the problems related to design and construction of earth dams, as well as the solutions normally adopted in Mexico. Although the fundamental ideas on this particular are fairly well-known, the facts observed by Mexican engineers through more than two decades of intensive work on this field of endeavor are considered of great value to the Engineering Profession. In closing this article, it only remains to say that, except for the defficiencies mentioned in this paper, behavior of the dams constructed by the Secretaria de Recursos Hidraulicos has been satisfactory.

The authors are greatly indebted to Messrs. Aurelio Benassini V., Chief Engineer of Irrigation and River Control ; Antonio Coria, Head Engineer of the Consulting Department ; Oscar Vega Arguelles, Director of Project Planning and Design ; and Raul Sandoval L., Head Engineer of the Papaloapan Commission, for their valuable suggestions and cooperation.


Crest
Core
Rock-fill
a
LONGITUDINAL CRACKS DUE TO DIFFERENTIAL SETTLEMENTS OF THE ROCK-FILL
b
Dam Crest El. 71.50m
Original Section of the Dike
Section After Failure of the Rock-fill
Natural clay deposit (CH)
c PESCADITOS DIKE


NOTE: Figures attached to the observation wells are the elevations of the water surface, in meters.
N
S
W
E
Observation Wells
Pumping Well
LEVEL LINES OF THE WATER SURFACE
PUMPING DISCHARGE = 140 l/sec
LENGTH OF THE TEST = 180 h.
ABELARDO L. RODRIGUEZ DAM
PERMEABILITY TEST PERFORMED IN THE FOUNDATION
a
b
c
SANALONA DAM
PERMEABILITY TEST
PERFORMED IN THE CORE


EXCAME DAM
STATE OF ZACATECAS
DAM CREST, El. 1701.00
Cracks
Spillway Crest, El. 1700.55
PROFILE OF THE SITE
SETTLEMENTS OF THE CREST
ELEVATION, in meters
SETTLEMENT, in centimeters
NOTE: Settlements measured in May 1955.
The Dam was concluded in August 1949.
TRUJILLO DAM
STATE OF ZACATECAS
DAM CREST, El. 2132.35 m.
Crack
Crack
Spillway Crest, El. 2123.75
PROFILE OF THE SITE
SETTLEMENTS OF THE CREST
NOTES: The maximum water level in the reservoir, was of El. 2128.75 m. (November 1953).
Cracks were observed in December 1953.
Settlements measured in April 1955.
The Dam was concluded in May 1949.
EXCAME DAM
CRACKS IN THE IMPERVIOUS CORE
TRUJILLO DAM

MECHANICAL PROPERTIES

DAM	MECHANICAL ANALYSIS (W I T) (TOTAL SAMPLE)				ATTERBERG LIMITS (FINER THAN Nº 40 SIEVE)				STANDARD COMPACTION (FINER THAN Nº 4 SIEVE)				CLASSIFICATION
	G	S	M	C	Lw	Pw	Iw	s_s	γ_d	W_o	e_o	G_o	
	%	%	%	%	%	%	—	—	kg m^{-3}	%	—	%	
EXCAME	8	39	33	20	52	20	32	2.61	1635	19	0.59	86	*Highly compressible clay (CH)*
TRUJILLO	26	52	16	6	40	21	19	2.64	1760	16	0.50	82	*Clayey sand (SC)*

G = Gravel
S = Sand
M = Silt
C = Clay

Lw = Liquid Limit
Pw = Plastic Limit
Iw = Plasticity Index
s_s = Specific Gravity

γ_d = Dry Unit Weight
W_o = Optimum Water Content
e_o = Void Ratio
G_o = Degree of Saturation

FIG. 8

References

1. *Erdbaumechanik auf Bodenphysikalischer Grundlage*—K. Terzaghi, Leipizig, 1925.
2. *Machanics of Hydraulic-Fill Dams*—Glennon Gilboy, Journal of Boston Society of Civil Engineers, 1934.
3. *Simplified Computation of Vertical Pressures in Elastic Foundations.*—N. M. Newmark, University of Illinois, 1935.
4. *Hydraulik*—Philip Forchheimer, Leipzig 1930.
5. *Proyecto de Instrucciones Generales sobre las Operaciones de Inyectado de una Roca de Cimentacion*—Antonio Coria, Publication de la Secretaria de Recursos Hidraulicos, 1952.
6. *Kajraset I Goteborg den 5te. mars* 1916– K. E. Petterson, Teknisk Tideskrift, 1916
7. *Calculation of the Stability of Earth Dams*– W. Fellenius, Trans, 2nd Congress on Large Dams, 1936.
8. *Observaciones sovre el Analisis de Estabilidad de Taludes por el Metodo Sueco*– Raul J. Marsal y Enrique Tamez G., 3er. Congreso de Ingenieria Civil en Mexico, 1955.
9. *Notes on the Design of Earth Dams*– Arthur Casagrande; Harvard Soil Mechanics Series, Bulletin Num. 35, 1951.

Drainage Study of Lower Damodar Valley—II

By SATYAKAM SEN, M.A.

Hydrological Characteristics

Study of the hydrologic characteristics of the lower reach of Damodar form the subject matter of this chapter. The work discussed here include rainfall characteristics, evaporation loss, surface runoff, suspended load, tidal characteristics and the movement of ground watertable of the area under consideration.

Rainfall Characteristics

Rainfall pattern from the survey of previous workers

V. Satakopan, K. N. Rao, and S. K. Pramanik 11 have done much work on the Upper Damodar Catchment basin and the pattern and frequency of rainfall in the upper valley. Their results show considerable influence of rainfall on the river flow in the lower valley. The transition stage between the two valleys is found to have very little valley-storage.

Satakopan was in fact the first to make a comprehensive study of the rainfall over the entire Damodar Valley.

The following information can be obtained from Satakopan's report 12 on the rainfall studies in connection with the unified development of the Damodar river.

"The worst storm that has occurred over the basin of the catchment (upto Raniganj) gave a mean rainfall of 11.9 inches in five days over the basin in August 1913. The highest mean rainfall that has occurred in a day over basin area of the catchment was 4.9 inches, in August, 1935.

A storm giving more than 13 inches mean rainfall over the catchment basin may occur once in about 65 years and a storm giving more than 15 inches rainfall may occur once in about 120 years."

It is further reported by the same author that the characteristics of the worst storm that can occur in the neighbourhood of the catchment are 22 inches rainfall in 7 days, out of which 15 inches may fall in 3 days and 8 inches in one day, all over 7,200 sq. miles. Considering the orographical features, and the past history of rainfall incidence in and near the catchment it is considered that the probability of such a storm occurring over the catchment is extremely small and that it may be neglected for all practical purposes. A storm giving 18 inches rainfall in 6 days of which 13 inches may fall in 3 days and 7 inches in a day may be assumed as the maximum that is likely to occur over the Damodar catchment Basin for all practical purposes.

During storm periods when heavy rainfall is recorded over the Damodar Basin the lower Damodar catchment gets generally a mean rainfall equivalent to 75% of the mean rainfall over the basin area of the catchment.

S. K. Pramanick and K. N. Rao in their memoir, "Hydrometeorology of the Damodar catchments" (Memoirs of the Indian Met. Dep. Vol. XXIX Part VI 1953), have examined the rainfall data for the upper valley down to Asansol extending over a period of 60 years from 1891 to 1950. They arrived at the following important conclusions.

The main surface wind directions in the catchment from June to October are either from E to W or from SW to NW.

The difference in the normal rainfall of the catchment of June to Sept., June to October and annual based on data upto 1940 and upto 1950 is negligible.

The mean rainfall of the catchment is 45.8 inches from June to September. 45.1 inches from June to October and 51.2 inches for the year.

The distributions of seasonal rainfall and rainy days (June to September and June to October) are normal.

There has been no significant change in rainfall from 1891 to 1950.

The distribution of daily rainfall during storm periods of 5 to 7 days has been examined and it is found that :—

(*i*) on occasions of 5-day rainfall exceeding 7.5 inches generally, more than 75% of the rainfall had occurred in 3 consecutive days.

(*ii*) on occasions of 6-day rainfall exceeding 9 inches generally, more than 75% of the rainfall had occurred in 3 days.

(*iii*) on occasions of 7-day rainfall exceeding 10 inches generally about 65 to 70% of the rainfall had occurred is 3 days, and about 90% of the rainfall in five days.

A study has been made of storms in the neighbourhood of the catchment and the question of transposition of storms has been considered. Even on occasions when the tracks of the storms were over or near the catchment, much heavier rains than what

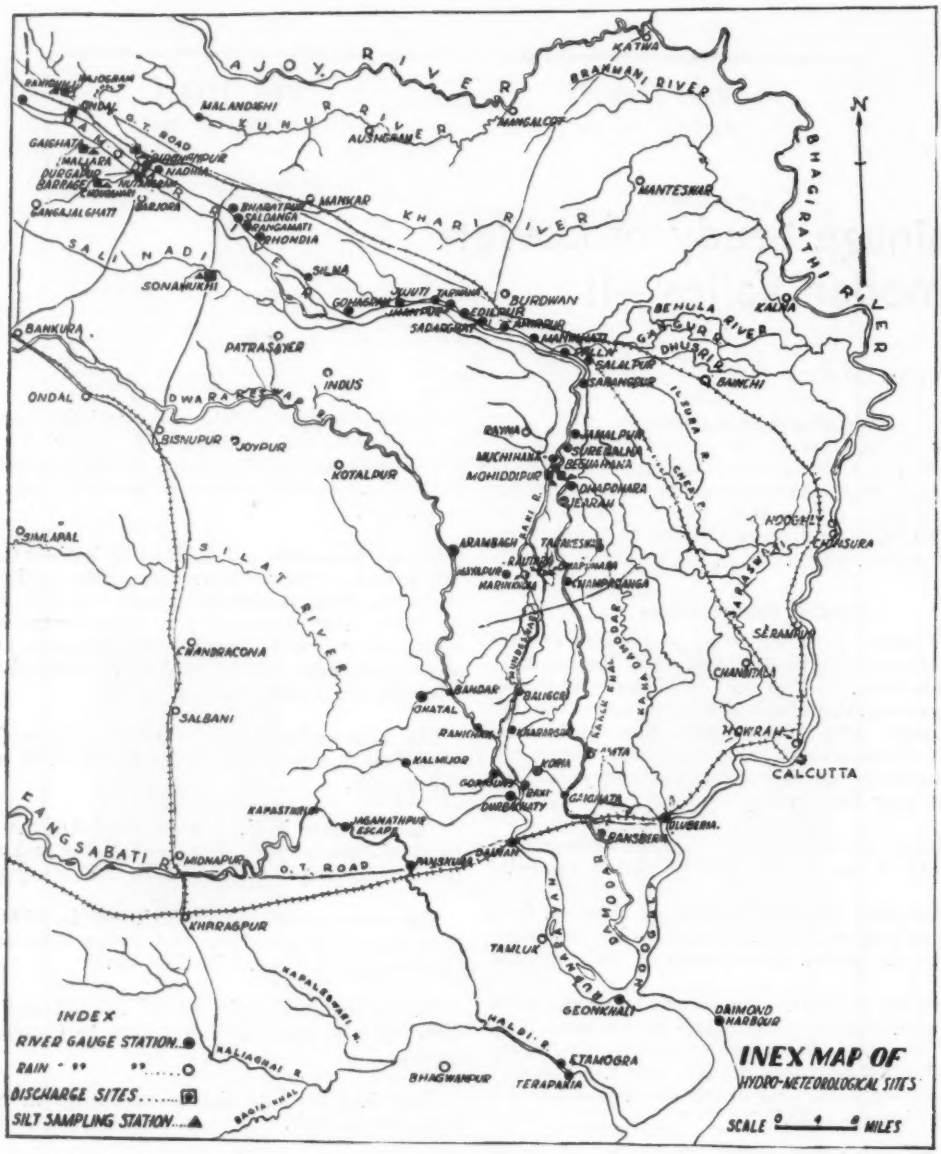


Fig. 16

occurred over the catchment fell in its neighbourhood only. This would suggest that while transposing storms in the neighbourhood to the catchment the magnitude of the storm is likely to be affected.

High discharge at Rhondia (exceeding 200,000 cusecs) on any date is very highly correlated with the rainfall recorded on that date as well as the preceding two days. This is also true of peak discharges.

Discharge of the Damodar river at Rhondia on any day is very highly correlated with the following.

(*i*) Rainfall of preceding day (0.73)
(*ii*) Rainfall of preceding two days (0.80)
(*iii*) Rainfall of preceding day and discharge of preceding day (0.82).

The regression formulae are :—

(*i*) $D=0.3979\ D_1+5.7953\ R_1+0.4275$ (D in 10,000 cusec)
(*ii*) $D=4.35(R_1+R_2)+0.9703$ (D in 10,000 cusecs)
(*iii*) $D=71.70\ R_1+14.6757$ (D in 1,000 cusec).

Geographical distribution of precipitation.

Systematic rainfall records of the lower Damodar Valley exists from 1891. From those rainfall records the isohyets are drawn to show the average annual rainfall in the valley. The area under investigation is located under the tropical monsoon precipitation regime where the normal annual rainfall lies between 50 and 60 inches. The isohyets here are not very irregular. Rainfall decreases from south east to north west. In the upper Damodar catchment the annual rainfall is less than 50 inches. But in the lower reach

the rainfall is slightly higher, probably because the moisture source (i.e. Bay of Bengal) is nearer this area. The influence of local storms in the Bay of Bengal can be observed in the lower reach on account of the proximity of the Bay.

Fig 17 shows the distribution of annual rainfall.

Seasonal variation of precipitation.

About 90% of annual precipitation occurs during the period extending from June to October. It appears from the map (see fig. 18) that from November to April the amount of rainfall is insignificant. The rainfall increases during the month of May, and precipitation occurs considerably during June and July, that is following the burst of the monsoon. Later on, the amount gradually diminishes month by month excepting when there are occasional storms.

Rainy days.

The average annual number of rainy days as reviwed inthe map. (fig. 19) shows that the direction and the diagonal trend furnish the delimiting boundary conditions as regards the highest and the lowest values of the element. The intensity of the summer monsoon winds decreases appreciably towards northwest.

At Burdwan the average annual number of rainy days decreases with the increasing amount in the southwest. This shows that the frequency and intensity zones of rainy days show selection and directional trends in accordance with the prevailing wind system, in the context of the varied relief and landform of the Damodar valley.

Intensity and freguency of rainfall.

The table giving the frequencies of rainfall shows that the occurrence of rainfall is nil during the period running from February to April and also in December when clear sky is visible (see table no. 5 & 6) The frequency increases as the monsoon approaches. In May or early June, most of the rainfall is due to the nor'westers or Kalbaishakhis. The burst of monsoon takes place about the middle of June; thence onward the frequency increases. It ends with the beginning of the retreating monsoon currents. Most of the rainfall showers record upto 1.75 inches. As regards the showers which occur during the whole year, the larger number of cases record only 0.00 to 1.25 inch. Occurrences of rainfall above 2.50 inches are rare. In 1953 at Asansol in the month of August, there occurred 4 to 5 inches of rainfall.

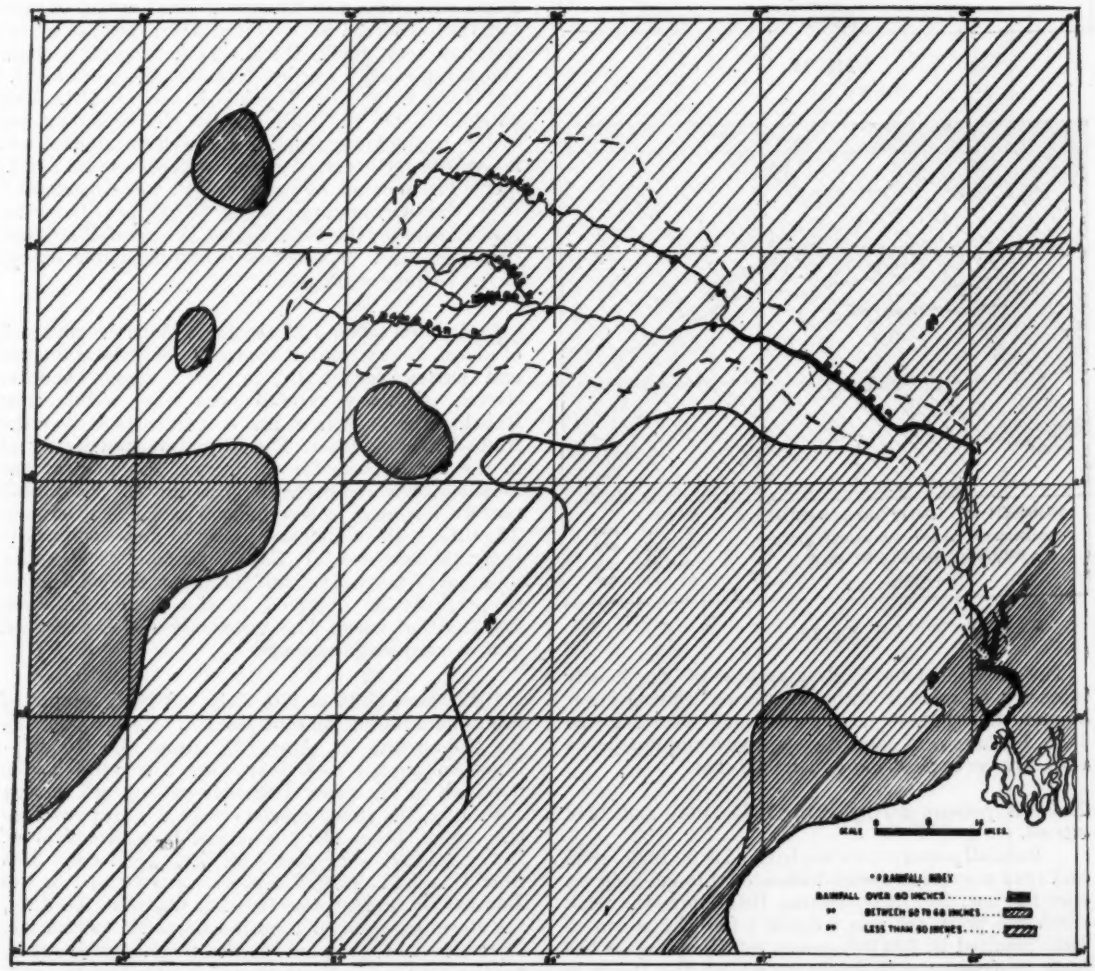


Fig. 17

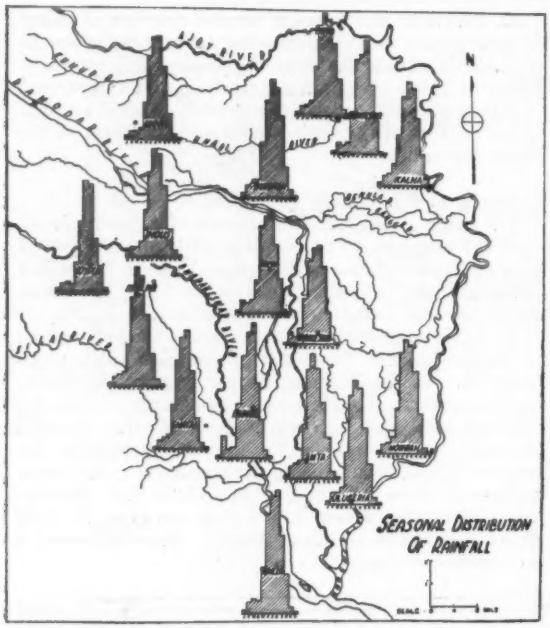


Fig. 18

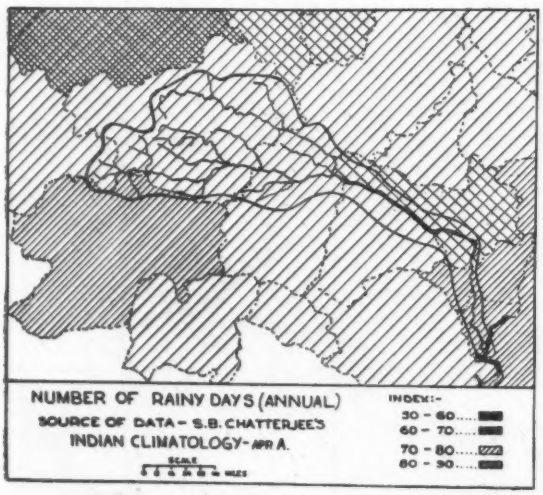


Fig. 19

The table (no 4 and 5) gives an idea of the hourly intensity of rainfall during 3 storms. During these storms, the highest hourly intensity recorded was 1.42. In this storm, falls in successive 5 minutes shows that it never exceeds more than 0.30 cent.

Rainfall pattern during 1913, 1935, 1941 *and* 1943 *storms.*

Rainfall patterns relating to the 1913, 1935, 1941 and 1943 storms have been delineated through isohyets (See fig. nos. 20,21,22). During 1913 storm the peak discharge produced was 650,000 c.f.s. The storm of 1935 resulted in 700,000 cusecs (at Rhondia) as the peak discharge ; such discharge during the storm in 1941 was about 650,000 cusecs (at Rhondia) and during 1943, 2,22,811 cusecs (at Rhondia). The storms of 1913 and 1935 occurred in the month of August, but those of 1941 and 1943, in the month of October and and July respectively.

1913 *Storm* (*6th to 11th August*)—On the 6th August Heavy rainfall shower occurred over the Midnapur and Orissa coasts. The amount of rainfall was considerable over the entire region. The showers were however negligible in the upper catchment; the lower point of the lower reach on the other hand had some rains. On the 7th August, the rainfall spread uniformly over the entire tract, but the amount was not very much. The rainfall on the 8th August was heavy in the upper Damodar catchment. More than 10″ precipitation occurred near Dhanbad. The isohyets of the 9th, 10th and 11th show that precipitation shifted towards the west and the north-west, ultimately the sky above the upper and lower Damodar valley becoming clear (See fig 20).

1935 *Storm* (*10th to 14th August*)—The approach of storm on the 10th August is visible from the isohyetal map (fig. 21)). In the lower reach, the rainfall amounted to about 1″ ; while 2″ rainfall occurred over the Topchanchi area near Dhanbad. The amount of rainfall that occurred all over the Damodar catchment was not very much. On the 11th August, a slight amount of rainfall was incident over the lower reach ; but it was high at the Topchanchi area and the Usri catchment. On the 12th August, the clear sky was visible in the lower reach, but a well distributed and heavy shower occurred in the upper Damodar catchment The amount of precipitation was considerable over the sorrounding areas of Upper Damodar Catchment. On the 14th August the rainfall amount decreased and became practically negligible except in the vicinity of Dhanbad.

1941 *Storm* (*8th to 10th October*)—With the approach of storm, heavy rainfall occurred along the Midnapur and Orissa (record 10″ in some areas). Another stretch of heavy rainfall area was visible near Ranchi. The 2″ isohyet line is seen to pass over the Amta-Khanakul tract. The rainfall was practically nil in the upper Damodar catchment, except near the Dhanbad area, and in the Usri catchment. The rainfall pattern was more or less uniform on the 9th October. The three high rainfall areas may be located from the isohyetal map viz: (1) Ranchi plateau, (2) Gangpur area and (3) Coastal tract of Midnapur. A good amount of precipitation occurred in the Topchanchi area and the Usri basin. The Amta tract also experienced quite a considerable shower.

1943 *Storm* (*15th to 17th July*)—A good amount of rainfall concentration took place in the lower reach (at Mahesrekha 1″, Amta 2″, Raina 3″, Hooghly-Chinsura tract 4″) on July 15th. The rainfall was not high in the upper Damodar catchment. On the 16th July, the storm moved from the lower reach to the upper Damodar catchment. Two stretches of heavy rainfall were visible tn the Topchanchi area near Dhanbad. Steep isohyetal slopes formed in the Barakar catchment near Giridth. On the 17th July, the storm passed over from the Damodar catchment. Rainfall then occurred in the neighbouring areas, particularly in the Northern and North-western areas of upper Damodar catchment.

The study of above storm conditions reveals that considerable amount of rainfall may occur in the upper Damodar catchment and its neighbourhood, in general. But the amount is likely to be heavier when the moisture-bearing winds are arrested by higher relief. In the upper Damodar catchment, there are two 2 zones of heavier rainfall, which bear a direct relationship to the topography. These two zones are: (1) the Topchanchi area and the vicinity of Dhanbad and (2) the Usri Basin, particularly in the vicinity of Giridih. In these two areas, the rainfall during all the storms were usually high, probably because of the direction of moisture-bearing winds (i.e. storm tracks) and higher relief. The rainfall amount in the lower reach is not high. In the Amta-Khanakul-Mahesrekha tract rainfall of 1″ to 2″ only occurred during all the storms; a small rainfall zone seems to exist also in the vicinity of the Chinsurah town near the Bhagirathi R.

Storm tracks

Storm tracks (fig. 23) available for the period, 1935 to 1943, reveal that the track lines change in direction with the approach of monsoon especially about the middle and the end of monsoon.

In July 1943, the track moved from south-east to north-west passing through Amta-Khanakul, in the lower reach of Damodar, in an angular direction upto Purulia, thereafter moving almost in an westernly direction. The trend lines of the August tracks in 1935, 1940, 1942 were westernly in direction. The 1935 track appears to move in a straight line from east to west from Jamtara (Santal Pargana) to Adaura (Shahbad district) of Bihar. A similar trend is shown by the track line of the 2-3rd August of 1942 which also moved from east to west almost in a straight line over Orissa. But the October storm track shows different direction. It approaches from west to east, of course

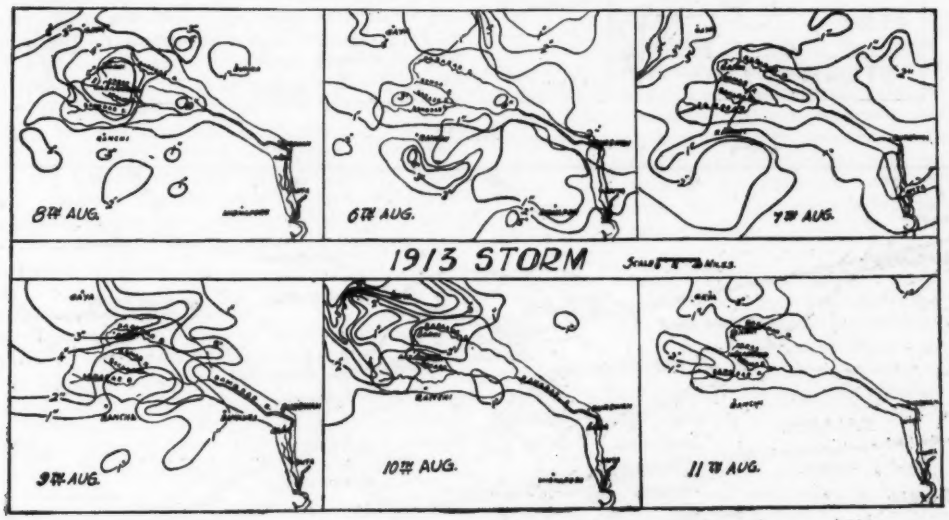


Fig. 20

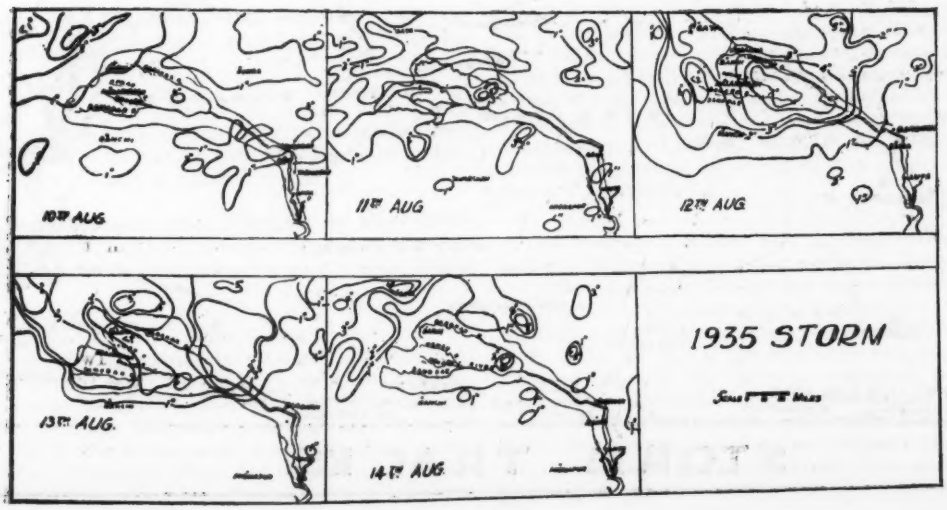


Fig. 21

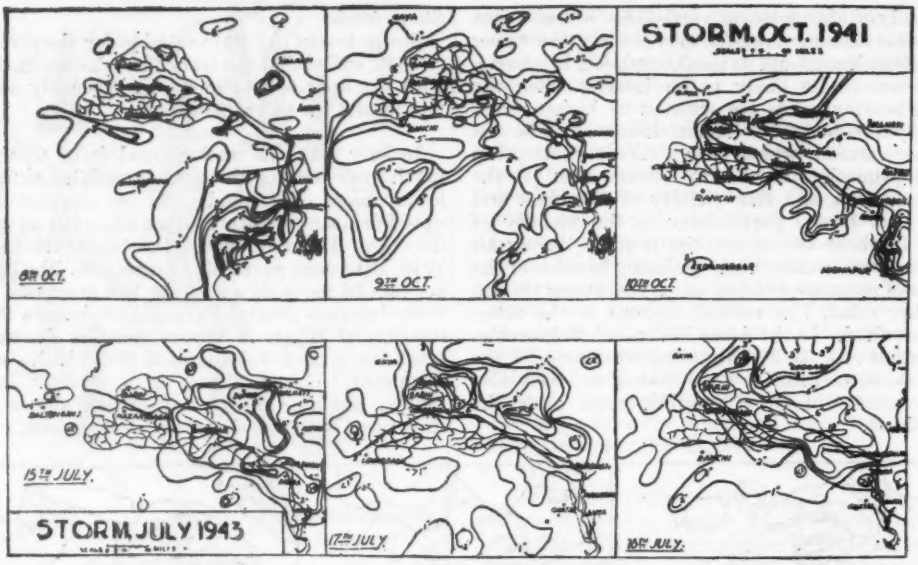

STORM, OCT. 1941
8TH OCT.
9TH OCT.
10TH OCT.
15TH JULY.
STORM JULY 1943
17TH JULY.
18TH JULY.

Fig. 22

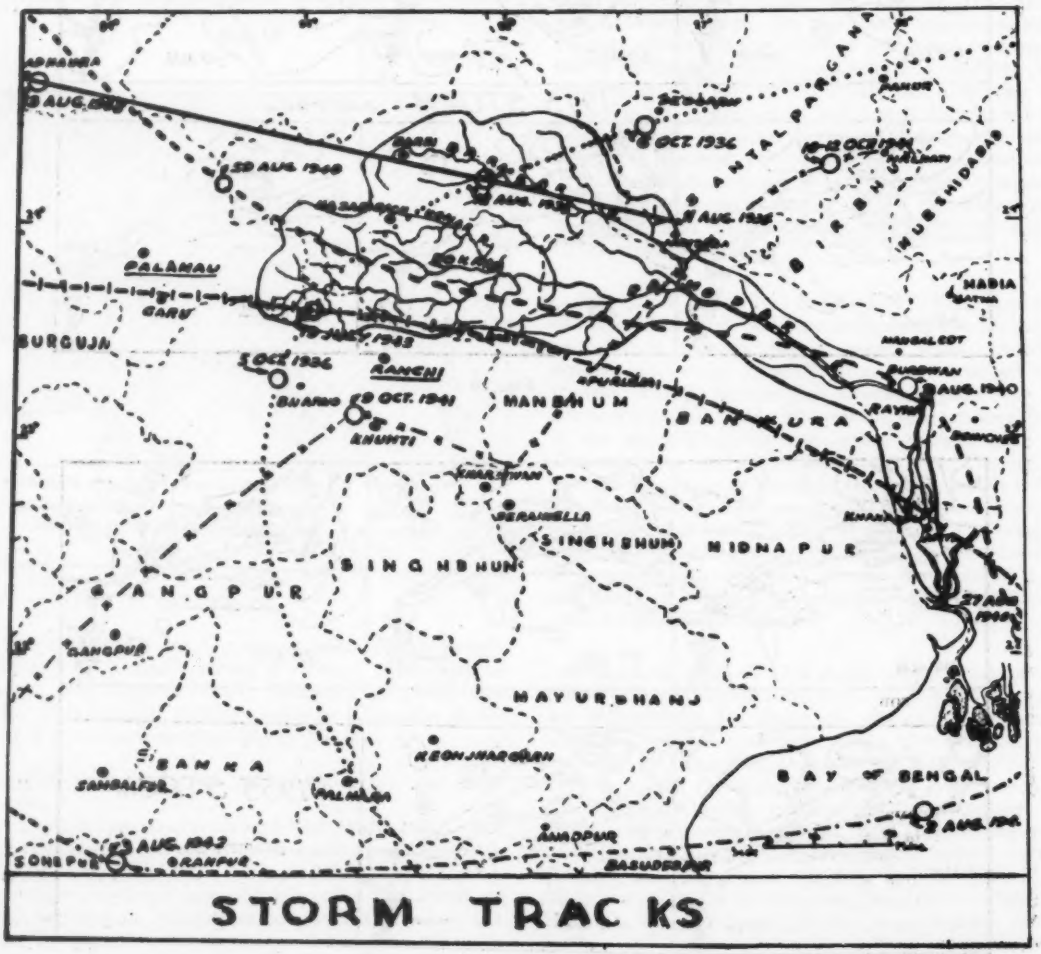

PALAMAU
GARU
BURGUJA
RANCHI
MANBHUM
SINGHBHUM
SINGHBHUM
MIDNAPUR
SANGPUR
RANGPUR
MAYURBHANJ
KEONJHARGHAR
BAMRA
SAMBALPUR
BALASORE
BAY OF BENGAL
SONEPUR
BARAMBA
HABIA
STORM TRACKS

Fig. 23

forming an arc. The October track of 1936, forming a semicirole, moved in an easterly direction towards West Bengal from Hazaribagh. Similar directional trend is observed with the track line of 1941. But in this case it is not semicircular in form. Two slight curvatures are however visible.

Evaporation

Evaporation is a physical phenomenon which takes place under all conditions wherever there is a water-surface. So far as the atmospheric conditions of any area are concerned, evaporation supplies all the moisture for precipitation ([13]) Study of evaporation of water from a river surface is therefore essential for the study of its hydrological conditions. To complete the study of the hydrological conditions of the lower reach of Damodar therefore, a study was undertaken in respect of the evaporation of the entire Damodar Basin.

Systematic collection of meteorological data for the Damodar Basin has been in progress since 1948. But systematically obtained evaporation data are however available from 1953 only. Of course, for the purpose of the present study, it is enough to condsider the data for one year ; so, those for 1954 have been adopted here for examination. There are six stations, namely Hazaribagh, Barhi, Ramgarh, Dhanbad, Bokaro and Panchet, in the upper catchment basin, and two stations namely, Asansol and Alipur, in Lower Reach, where data have been obtainod by using Piche evaporimeter. The results mentioned here are all stated in inches.

Evaporation in Damodar Basin

The estimated annual rate of evaporation, according to D.V.C.(as indicated in planning reservoir operation), is 5 ft. during the day period of the year. During this time, beginning with 3 inches in the latter half of October, it is distributed over the months of November to June respectively as 6,5, 3,6,7,8, 10 and 10 inches, under the normal conditions of weather.

During the monsoon months (July to mid-Oct.) no allowance is made in the records for losses owing to high humidity and high runoff co-efficient over the reservoir area.

Indian Met. Dept. has also confirmed that the annual evaporation loss is 5ft., from their observations.[14]

R. K. Misra, an agricultural meteorologist, estimated the total loss of moisture on account of transpiration and evaporation from the Damodar catchment at 22 inches per year[15].

Evaporation loss from February to May (1951) is about 1 ft. roughly in 4 weeks during summer as against the loss of 1ft. roughly in 6 weeks during winter.

Climatic Variation of Evaporation

The daily evaporation data have been calculated by the formula $E=V/2\pi(r_1^2-r_2^2)$, in which r_1 and r_2 respectively indicate the radius of the filter disc and the base of clip, E denotes the evaporation per unit area and V, the water in c.c. lost from the evaporimeter in a given unit of time. In the graphical presentation of the acquired data, the values of E have been plotted against the respective stations. The results of this graphical analysis, carried out on the data for 1954, are indicated hereunder. It is found from (figure no. 24) that the evaporation increases during the months, March to May, and drops remarkably in June ; and again in the months of August to September the evaporation is low in comparison with the other months of the year. Thereafter, from October, evaporation again rises, but the fluctuation is rather small.

Considering all the 8 stations, the evaporation curve rises to the highest in the Panchet hill station (nearly 1.15 inch) whereas in other stations, except in Alipur, the curves rise to somewhere between 0.60 and 0.90 inch. In Alipur, the variation of evaporation is not very notable. It does not rise above 0.30 inch, although evaporation during the period, March—May, is comparatively higher than during the other months. From these, it is apparent that Alipur is very probably under the sway of the moist wind from the Bay of Bengal.

It is also seen from the graph that there is rise during the pre-Monsoon period (i.e. March to Mid-June), there occurring a sudden drop during the rainy season when humidity is comparatively high. The evaporation is also low in the months of August—September (rarely it rises above 0.20 inch) but a rise again takes place in November. From October to December, though the evaporation curve rises, daily fluctuation is rather small.

Geographic Variation of Evaporation

The amount of variation is not the same at all places. It varies with altitude and the extent of water surface. The evaporation is found from both graph and table to either increase or decrease with altitude ; sometimes it decreases after increasing and at others, it increases after decreasing.

Considering the monthly average values (in inch) given in the table, one may say, in general, that evaporation increases with altitude. (See table 7)

But there are some difficulties about such simple conclusion. In Panchet hill it is observed that evaporation is always high relative to what obtains at all the other stations, while the altitude of this station is only 391ft. On the other hand, evaporation is lower at Bokaro (784ft.) Of course at Dhanbad (815ft.) increase in evaporation is visible. But again a decrease at Ramgarh (1069.71ft.) is noticed. The variation of evaporation in Barhi (1300ft.) and Hazaribagh (2019ft.) is more or less similar, with only slight difference. (See table 7).

The conclusion which can be derived from the columns of overall range and maximum evaporation for different months is that the range of variation is the greatest at Panchet hill (1.10 inch) and rather low at Bokaro (0.69 inch), Ramgarh (0.57 inch and Barhi (0.80 inch). So also is the maximum evaporation for different months. The relative difference regarding minimum evaporation for different months is slight in all the eight stations under investigation. It is found to be relatively high at Panchet hill (0.03 inch) ; and then it decreases, and becomes almost nil, at Dhanbad and Alipur.

Rainfall and Evaporation

High evaporation is observed when the amount of rainfall is low. Again, when the rainfall increases evaporation decreases (fig. 24).

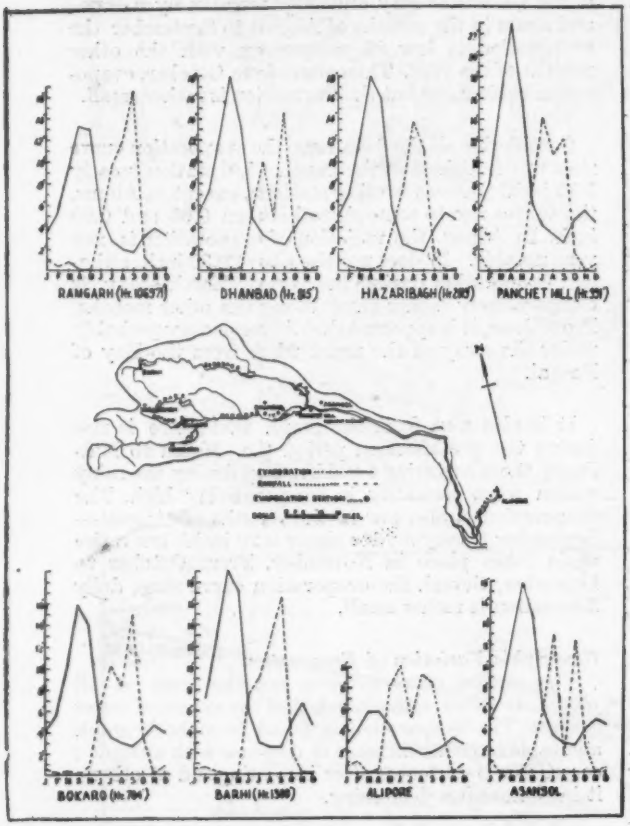


Fig. 24

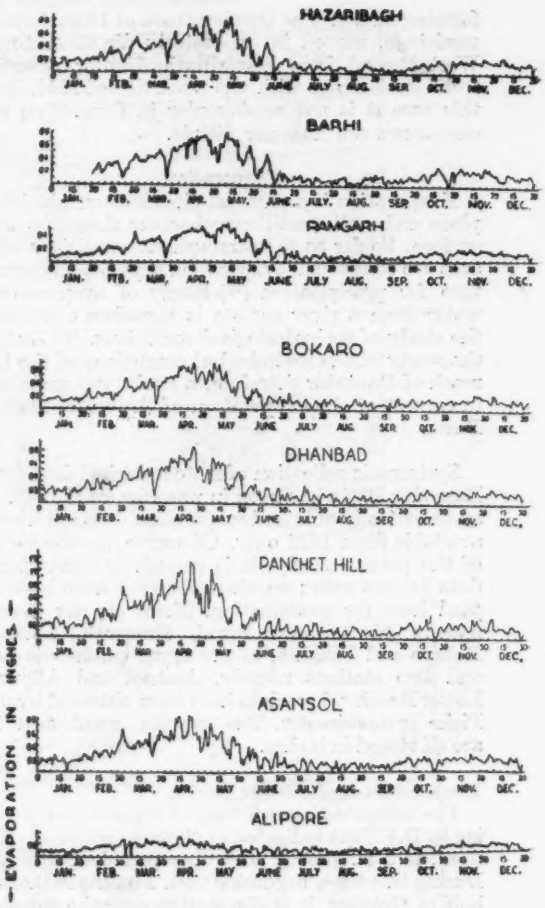


Fig. 25

Evaporation is greater in amount in pre-monsoon and post-monsoon periods when the rainfall is practically nil. Two sharp peaks are found for evaporation and rainfall. In April, evaporation is at its zenith and rainfall also reaches a peak mostly in the month of September. In Alipur and Ramgarh the evaporation curve does not rise beyond that of the rainfall. It shows that as we proceed towards west, the evaporation increases.

In post-monsoon season the rise of evaporation takes place, but the rise is of smaller magnitude, because the soil remains wet after the rains. However, as the soil becomes drier, the evaporation curve also rises.

Climato Geographic Variation of Evaporation

From the study of climatic variation of evaporation, it is clear that during summer months (March-May) the maximum range of evaporation is higher than during the other months of the year. With the approach of rains, a marked decrease of evaporation is observed (see fig. 25). A more or less steady value is found to occur in the Post-monsoon period, there being only a slight increase during the months of January and February. From the above graph it is also clear that evaporation is higher at Panchet hill, Dhanbad and Hazaribagh, during the winter and summer months, than at the other stations. But evaporation is relatively high at Barhi to what obtains at Hazaribagh during the rains, and also in autumn. But the altitude of Panchet hill, Dhanbad and Barhi, though high, is not very much so, relative to the adjacent stations. So, altitude is apparently not the predominant factor in the distribution of evaporation within the region. Leaving aside Panchet hill, it is observed that the evaporation decreases as the altitude increases.

Runoff characteristics

In this section the runoff characteristics of the main stream Damodar in its lower reach ond also its tributary streams, spill channels and drainage behaviour of the Trans Damodar area have been examined in details.

Stage-Discharge Relations

Rating curves are drawn relating to some of the hydrological observation sites in order to find out the stage-discharge relationship (See figs. 26,27,28,29). From these, the following facts can be noted.

The scatter of points at the Damodar Bridge site on the Damodar R indicates a regular and smooth curve. The stage-discharge curve is a generally well-

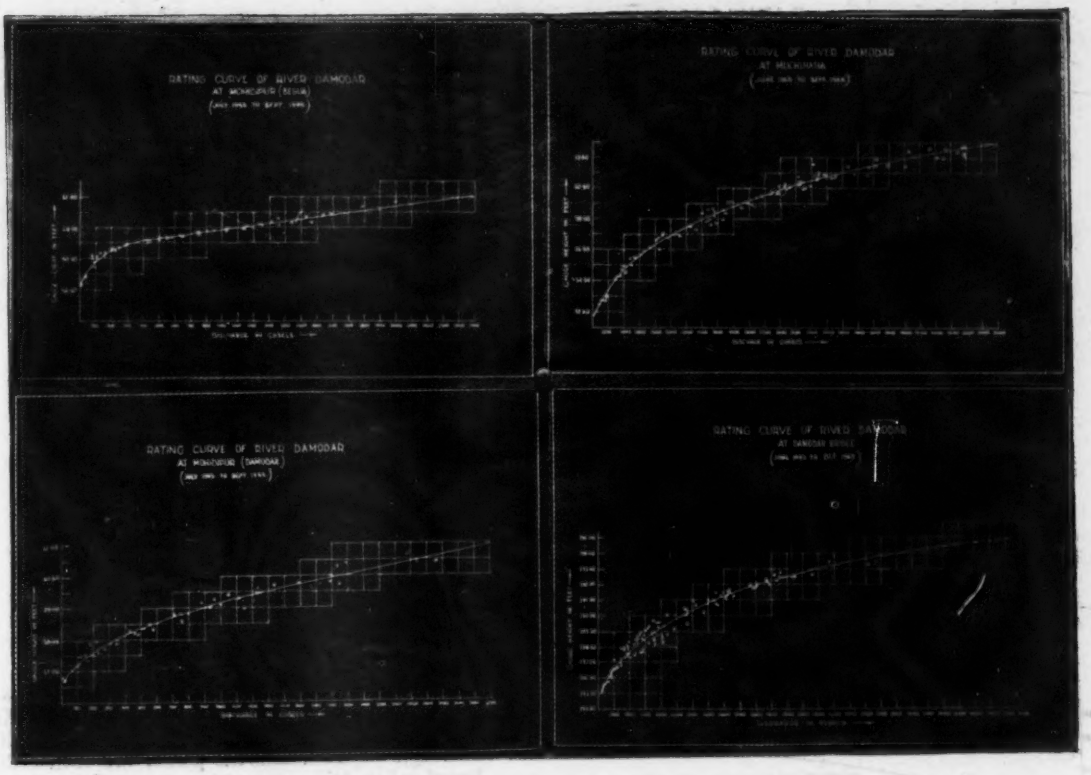

RATING CURVE OF RIVER DAMODAR
AT MOHUDIPUR (BIHAR)
RATING CURVE OF RIVER DAMODAR
AT MOHUDIPUR (DAMODAR)

Fig. 26

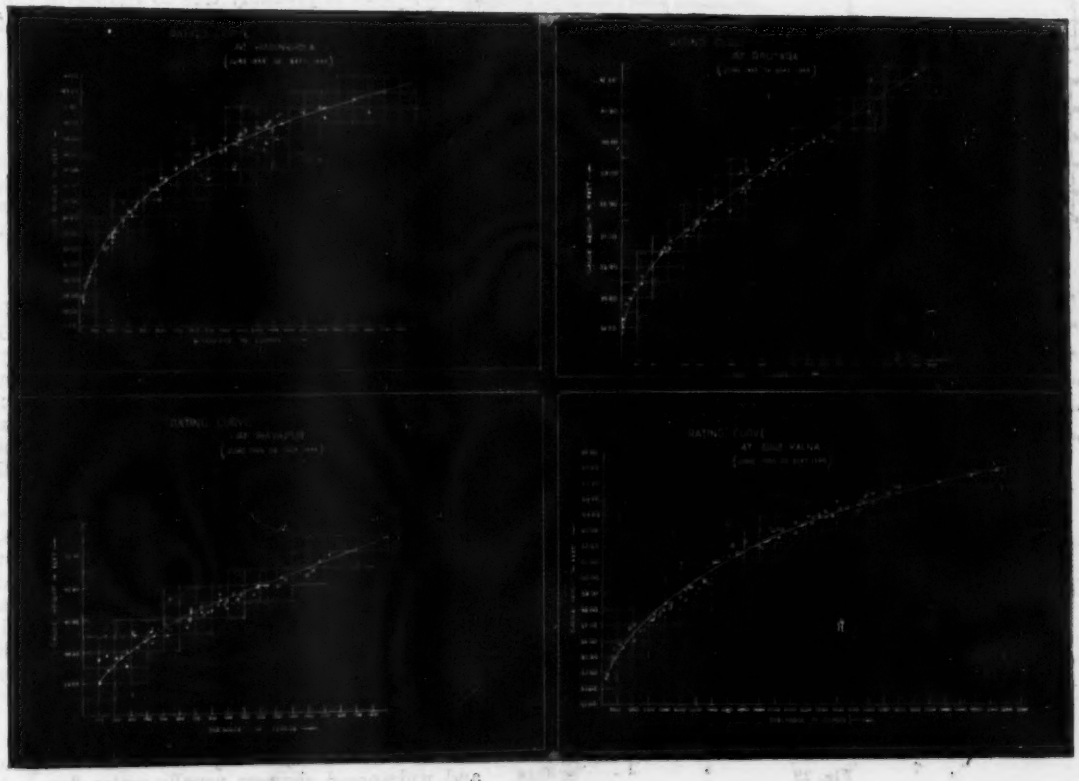


Fig. 27

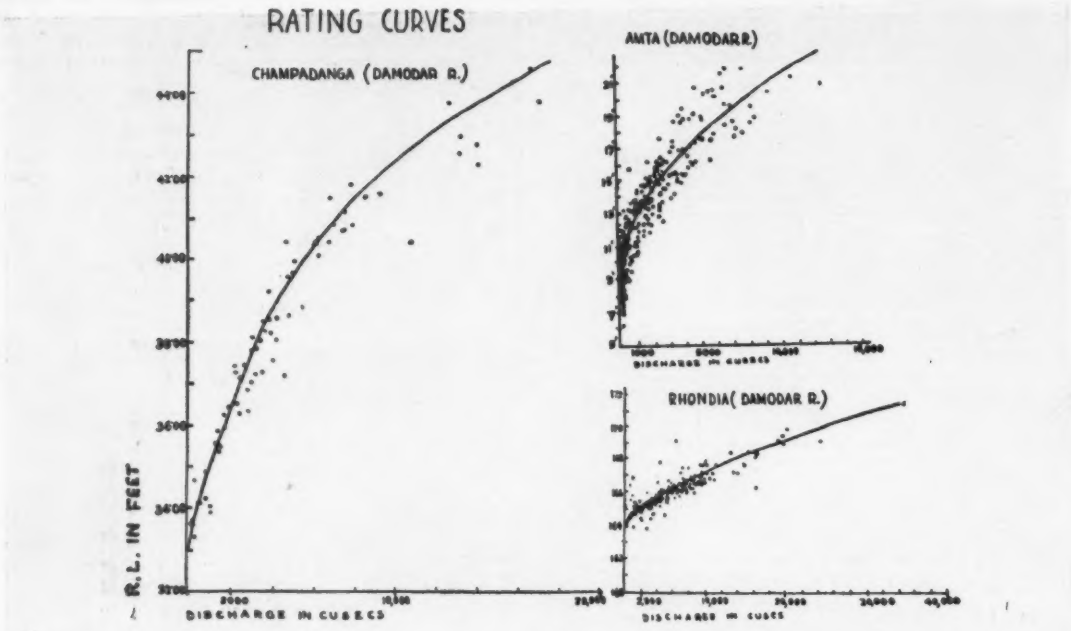


Fig. 28

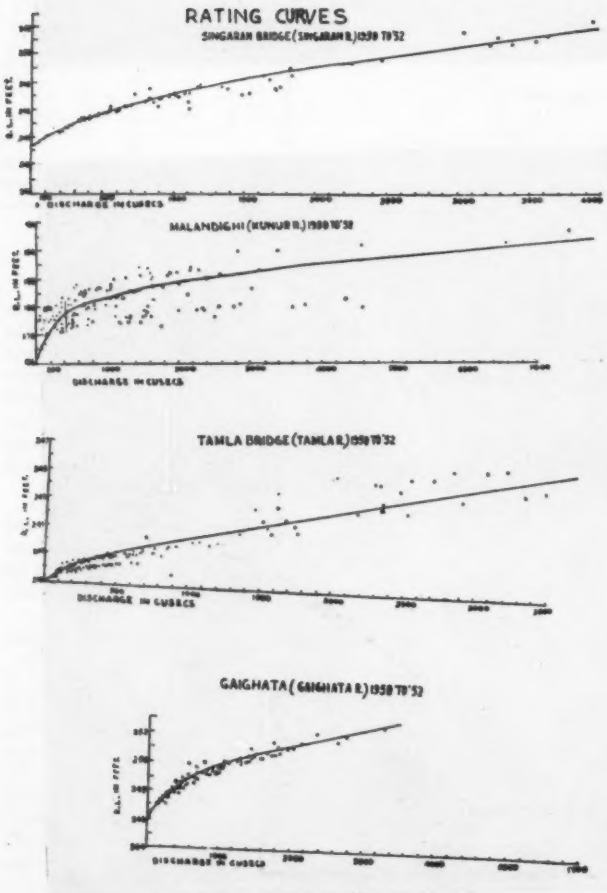

RATING CURVES
SINGARAN BRIDGE (SINGARAN R.) 1959 TO '52
MALANDIGHI (KUNUR R.) 1959 TO '52
TAMLA BRIDGE (TAMLA R.) 1959 TO '52
GAIGHATA (GAIGHATA R.) 1958 TO '52

Fig. 29

fitting one for Rhondia but the scatter points are rather dispersed at the lower stages. For Sure Kalna and Muchihana the rating curve is fairly well-fitting although for Muchihana the points are rather distributed where those curves correspond to different floods that occured in the months of July and August (1955). This is probably due to change in the bed-level, the contour and the difference in velocities at the same gauge heights.

At Mohiddipur (on Begua khal) the curve is small but smooth. Most of the points are concentrated at the lower stage (upto 1200 cusecs); and a very small number of scatter points is found at higher stages. However, at Mohiddipur (on Damodar R) although the curve is smooth, and fitting, upto 1,000 cusecs, the points are scattered to a greater degree at the higher stages.

Recently Discharge observations (in 1955) were taken in Kabla Nalla, Mundeswari R, and Harina Khal in the Trans-Damodar drainage areas. From these a smooth rating curve is obtained for Mayapur (on Kabla Nalla), and most of the points are concentrated at lower stages. At Harinkhola (on Mundeswari R.) the scatter of the points is prominent at higher discharges. These points all correspond to flood discharges with high velocities in the months of July and August. The rating curve is also a well-fitting one at Rautara (on Harina Khal) at the lowest stages, but it does not fit well at the higher stages. On the Champadanga area of Damodar R. the stage-discharge curves have been obtained for two stations viz. Champadanga and Amta. At Champadanga the points of the rating curve are scattered at the higher stages. The smooth fitting rating curve at the lower stages, with a more scattered one at the higher stages, are found for Amta.

Runoff Characteristic of the Damodar River

River Damodar is a flashy stream. Following heavy and widespread showers usually water flow is high.

Accepted D.V.C. run-off ratio during flood period is 90 per cent. [16] In 1943 one flood between the 15th and 20th July was followed by another extending from the 3rd to the 10th August ; this being caused by rainfall of 8.08 inches over a period of six days, there was a surface runoff of 4.89 inches during the flood period, yielding a ratio as high as 60.5 percent. Table No 11 shows the recorded high peak flows in the Damodar R. at Rhondia (run-off expressed in inches). The usual percentage of rainfall-runoff ratio (as calculated from the recorded floods between 1944 and 1950) at Rhondia is between 30 to 45 percent. (See table 12).

Average histogram and daily flow curves at Rhondia show (see fig. 30) that the runoff behaviour of the Damodar river system is like that of all monsoon-fed rivers of India. About 90 percent of the discharge occurs between June and October (Monsoon months) and the river-system is practically dry during the remaining months.

Hydrographs at Rhondia (see fig. 30) depict the the close relationship between rainfall and runoff. with the arrival of showers, the flood crest rises. In most cases a steep rise is found in the flood hydrographs, but the fall in most cases is not so sharp as the rise.

Table No 13 shows the highest discharge at Rhondia and the corresponding high flood level as recorded at different gauge stations along River Damodar from 1935. It shows that above Jamalpur, variation in the maximum flood level is conspicuous for the varying flood intensities. Below Jamalpur, particularly in the Champadanga area, it is not so conspicuous as at the gauge stations above it.

By analysing the discharge at Rhondia, and just at the bifurcation point (i.e. Mohonddipur Kaki and Mohiddipur Damodar), it appears that probably (see Table) a good quantity of water is being lost during flow from Rhondia to Mohiddipur. It is also observed from the Hydrographs (see fig. 31) that the discharge at Rhondia increases above that of the Damodar Bridge site, but the flood discharge decreases considerably at Jamalpur or Mohiddipur (Damodar) in comparison with that at Rhondia. Also, at Mohiddipur, much of the Damodar discharge flows through Kaki. This unaccounted loss may probably be the spillwater.

It is to be noted that the tributary rivers like Singaran, Tumla etc. also consumes quite significant amount of water availed of from the Damodar floods. By analysis of different floods it seems that so far as the small river channels are concerned, e.g. Malandighi on Kunur river, discharge is high. The peak discharge sometimes reaches upto 6,500 cusecs in floods (see Fig. 32). The peak discharge through Singaran is about 5,000 cusecs and through Tumla, about 4,000 cusecs approximately.

Below Anderson Weir, two other streams, Kookooe R. and Sali Nadi, which may also be mentioned. This Kookooe is a very small stream having a maxim-

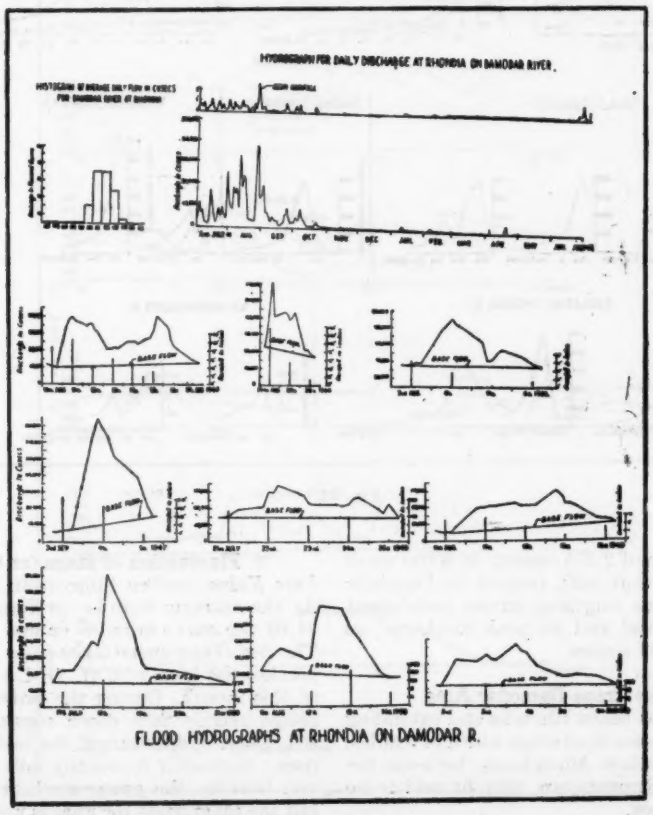


Fig. 30

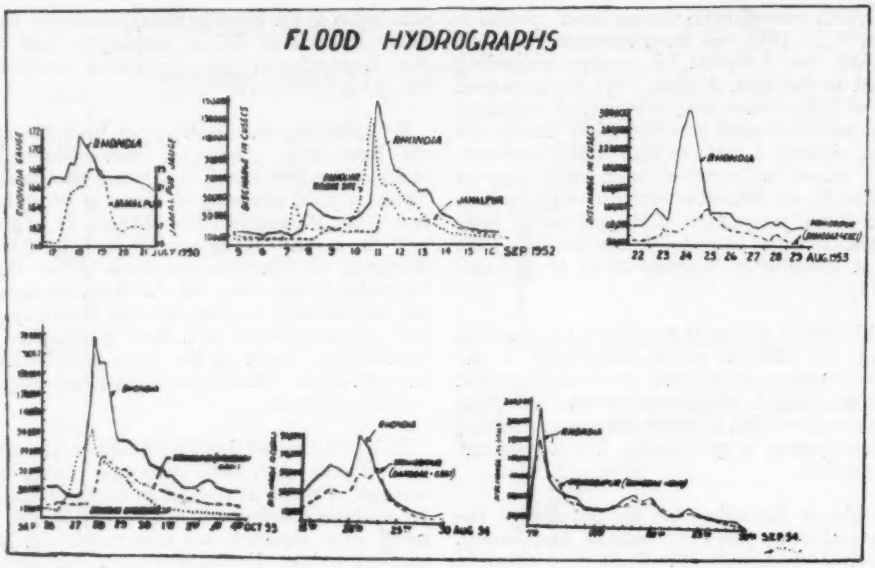


Fig. 31

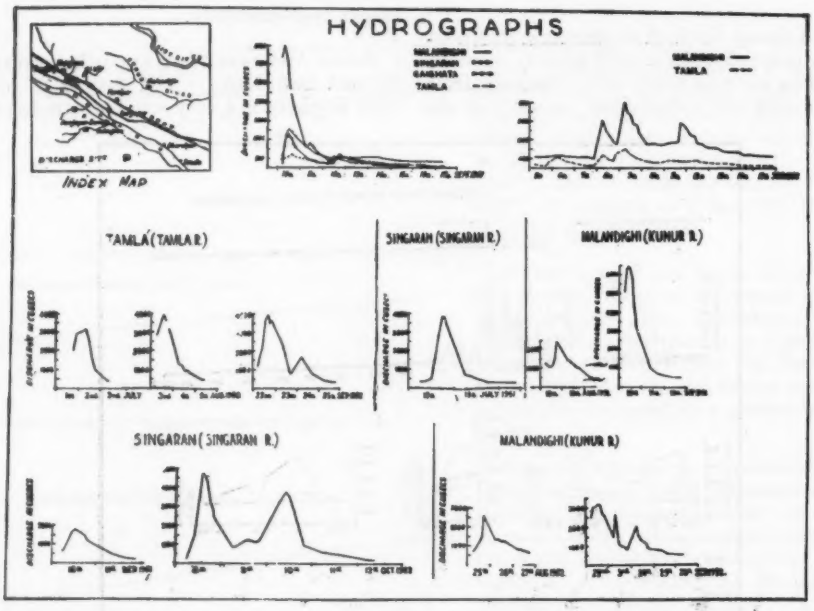


Fig. 32

um observed discharge of 2,275 cusecs. It is too small to be of much important with respect to Damodar discharge. Sali Nadi is a very long stream (catchment area is 232.72 sq. miles) and its peak discharge, as recorded here, is 50,643 cusecs.

Drainage in the Trans-Damodar Area

The tract of land just below Rhondia and extending unto Muchihana possesses an average width of 6 miles, and the whole area below Muchihana, between the rivers Damodar and Rupnarayan, may be said to be the Trans-Damodar area.

Fluctuation of Stage (or Gauge Heights)

Sure Kalna (before bifurcation of the Damodar R.) As the starting time i.e. in June, R.L. is near about 54.40 the curve is more or less steady during June. The rise of the curve takes place in July and the curve reaches the level of 67ft. (R.L.) during the last week of this month. During the latter half of August the gauge heights falls down considerably (below 56.00 R.L.) and again during the last week of August, it rises ; thereafter it steadily falls down. In September and October the gauge fluctuation can be observed but the magnitude (or rise) is not very high.

Mohiddipur (on Damodar R.)—In July, gauge height ranges between R.L. 57.00 and 61.00 ft. In August fluctuation is observed to occur, but in smaller magnitudes than those found in July. In September the water-level remains the same almost throughout the month. So also happens in October except for some minor rises.

Begua Nalla

In July, gauge height ranges between R.L. 57.00 and 62.00ft. In August the rise and fall of the curve are noticed but these are of smaller magnitude than in July. In September, the water level remains same throughout the month.

Muchi Hana

Water-level here is more or less of steady nature in June. The rise of the curve takes place in July. In August the level rises upto 62.50 ft. The river stage is high during August and September. In September the water level is of rather steady nature, although some fluctuation of smaller magnitude than in July and August seem to occur. In October the rise and fall of the curve can be observed but the rise does not exceed 57.00ft. R.L.

Rautara (on Harina khal)—In June, the river bed sometimes remains dry. The rise of the water level takes place during the month of July. The range of R. L. is found to be between 31.50 and 41.50 in August. In September rise and fall of the curve can be noticed, but the rise hardly exceeds R.L.36.00ft. Fluctuation are also observed in October but the R.L. does not exceed 34.00 ft. The curve appears to to be flat in December.

Mayapore (on Kabla Nalla)—The water-level range remains for the whole monsoon period between R.L. 37.00 and 43.00. ft. The curve rises in July.

The trend of the curve during July and August shows that there are fluctuations of smaller magnitude than at Rautara (on Harina khal) and Harin khola (on Mundeswari R.). In September the curve becomes almost flat. Whereas the curve of Mundeswari becomes flat in the month of December, that of Harina khal does so in the month of September.

Hydrographs (1955)

Monsoon hydrographs of the Trans-Damodar Drainage areas clearly show (see fig. 35) that the rise of the curve takes place with the burst of monsoon and also that the peak flood discharges always follow by heavy showers in the upper catchment and in the lower valley.

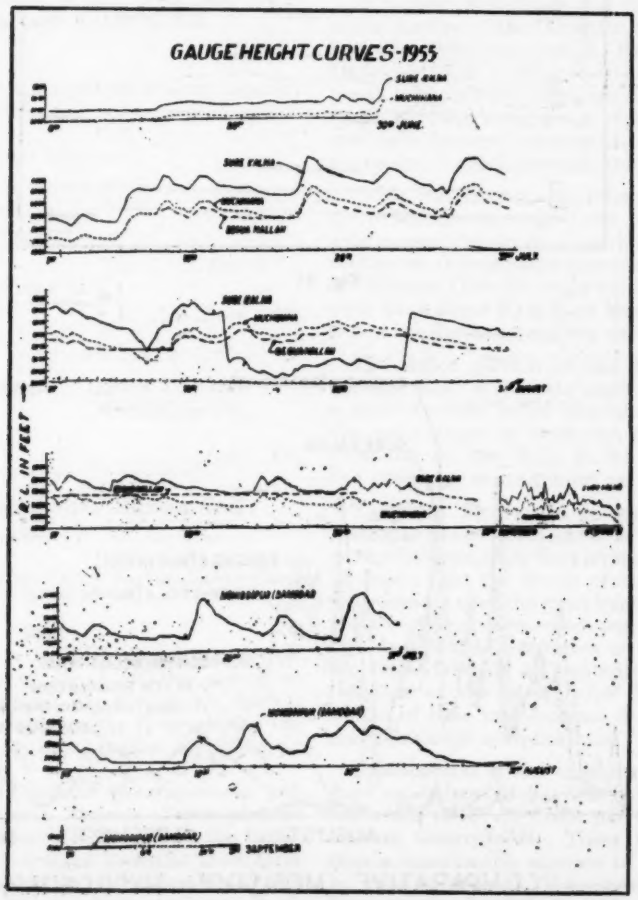


Fig. 33

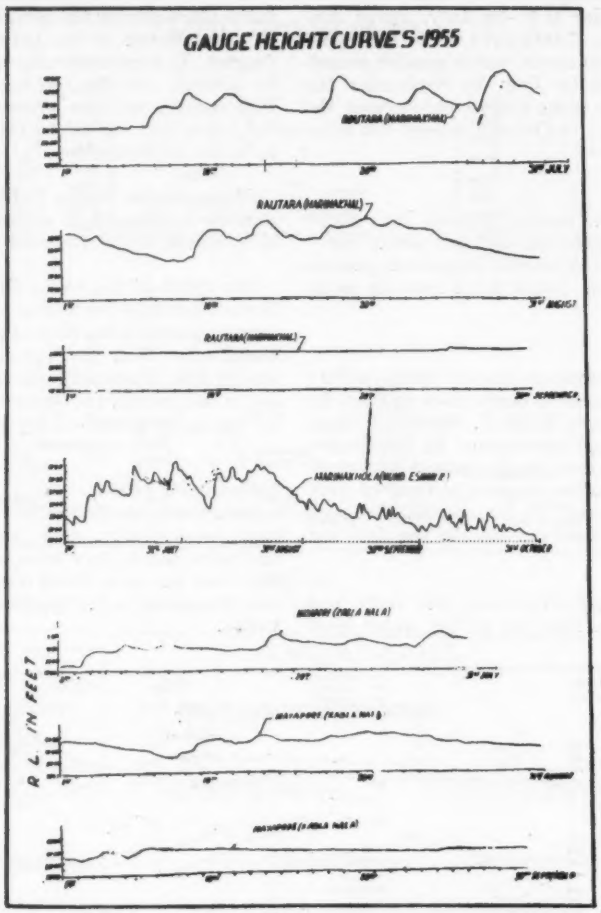
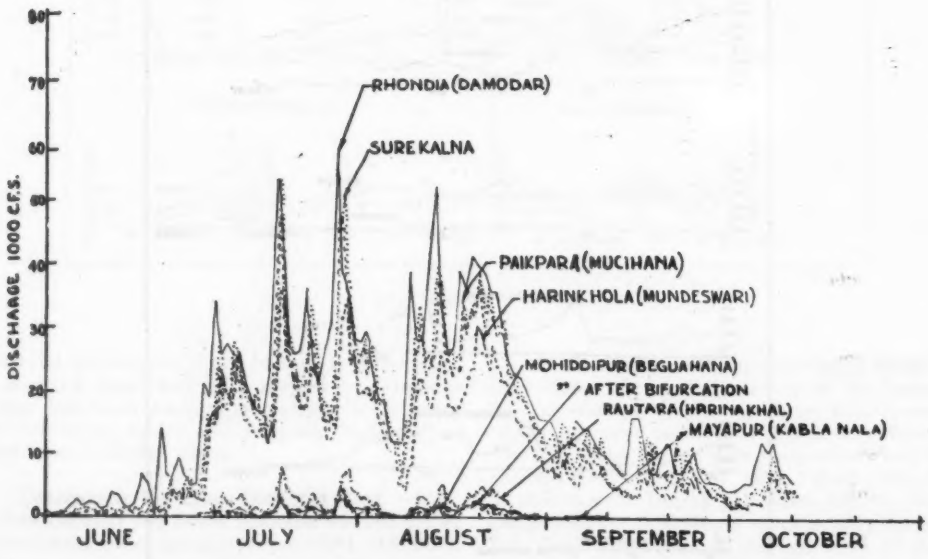


Fig. 34



COMPARATIVE MONSOON HYDROGRAPHS.

Fig. 35

Hydrographs of the Rhondia and Sure Kalna (on Damodar R.) show slight differences in the maximum and minimum of the curves. This is so probably due to the pressure of spill channels (hanas consume a good quantity of water which spread over to the lower areas).

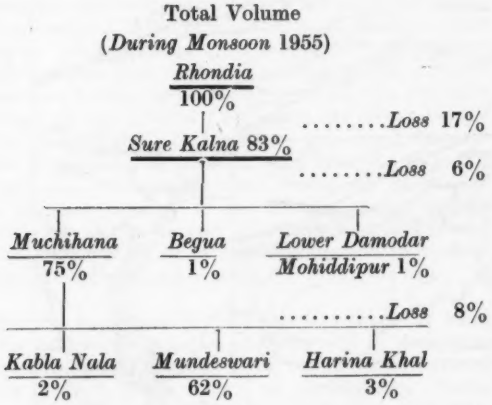
The curve of the Muchihana shows similar rise and fall to that of Rhondia or of Sure Kalna. Hydrographs of Rhondia, Sure Kalna and Muchihana offer evidence that considerable floodwater passes through the respective river-bed cross-sections. The peak flood discharge reaches upto 59,000 cusecs at Rhondia, 53,000 cusecs at Sure Kalna ; and 48,000 cusecs at Paikpara (Muchihana).

Hydrographs of Beguahana, and of Mohiddipur show that the discharge in the old Damodar is negligible, particularly in comparison with Kaki River. In September, Mohiddipur (Beguahana) and Mohiddipur (below bifurcation) are covered with stagnant water. In Pre & Post monsoon periods, the river bed is dry.

Hydrographs of the Trans-Damodar drainage channels (i.e. Harinkhola on R. Mundeswari, Rautara on Harinakhal, Mayapur on Kabla Nalla) show that considerable discharge flows through Mundeswari at Harinkhola. The peak flood reaches upto 35,000 cusecs at Mundeswari whereas the peakpoint in Hari nakhal at Rautara is 8,000 cusecs and at Maypur in Kabla Nallah 3,000 cusecs. A very small quantity of flood volume passess through Kabla Nallah.

Flood volume

The following chart will show the present capacity of the channels to flood water :—



Source of Data—Lower Valley Investigation Committee, 1955).

Spill

The spill occurs at a bankful stage (this corresponds to a discharge of about 200,000 cusecs at Rhondia) and a portion of the flood flow is diverted through hanas before the river attains the gutterful stage and finally inundate the country side.

The left bank of the Damodar has continuous embankment upto its tail end. Absence of embankment in the right bank is responsible for spill on the trans-Damodar side. The entire trans Damodar tract spills through the hanas (spill channels) in low floods and overtops the banks in high flood. According to P. C. Roy, the right bank of Damodar river has been kept open to the spill since 1854, and during the course of the last 82 years the spilled area has gained an elevation varying from 5′ to 10′ [17]. The spill across the right bank of Damodar. downstream, starts virtually just below the Anderson weir at Rhondia. The bank level at that place is high enough not to permit any moderate flood to top ones. But near Kumirkhola there are deeper and pronounced gaps in the right bank through which even normal flood of the Damodar can send down its spill to the low areas near Khandaghosh. Some of the gaps have been *masked* to shut the low floods (e.g. Kumirkhola, Mohanpur, Lacra).

Topography of the Trans Damodar area is responsible for the spread of spill in a fan-like shape. It does not spread southward more than 3 or 4 miles. Besides this, the spur is high enough to withstand floods of any intensity. The southernmost limit of the spill water is the Gaighata-Baxi khal. Spill areas in the Burdwan district appear to be more of gutter-shaped surface than flat one. So when the flood water enters the area, it finds difficulty in passing out into the river again, though the river level, has fallen after flood. Then the spill water flows close by, and parallel to, the Damodar river, and subsequently it spreads over and floods the entire portion of the Trans-Damodar area.

At present Muchihana and Beguahana take off the major portion of the Damodar discharge which passes just over them and feed R. Kaki. In fact, the river Damodar tends to flow to river Kaki through these hanas both in flood and during the dry season. As a result of it the lower reach of main Damodar R. has gradually become constricted. These hanas send discharges to R. Kaki through Debkhal and its branches.

Table No. 18 shows the river-levels at which hanas above Muchihana, spill. Table No. 19 depicts the spill area covered by floods of various intensities in different years. The amount of area flushed is greater below Muchihana Table 20 shows the discharge spilling over right bank above Kaki R. or Muchihana. Table No. 21 shows the discharge spilling over the area below Kaki.

The major portion of the flood discharge passes through Kaki R, and the main Damodar carries only a small fraction below Muchihana. Table 22 reveals the percentages of discharge passing through main Domodar R. and Kaki R. for diffierent years when the discharge is maximum at Rhondia.

Table No. 23, 24 and 25 show the discharge of Damodar above Muchihana, at Mohanpur and Amta at the different high flood levels. The tables 11,12 and 13 depict that the floods of various intensities spill considerably over the right bank whereas at Amta the volume of floodwater which passes through, is negligible. Any further restriction of the flood discharge in the Damodar will undoubtedly cause further deterioration of the river below Muchihana, which in course of time may become dry and thereby create many drainage complications.

Examination of the cross-sections reveals that the gaps are wide at Mohanpur, Kumir Khola and Barasat while these are quite narrow at Jakta, Jamda, Bhasna Gauripur etc. These facts evidently show that a considerable amount of flood discharge must be passing through Mohanpur, Kumir Khola and Barasat. (see fig. 37).

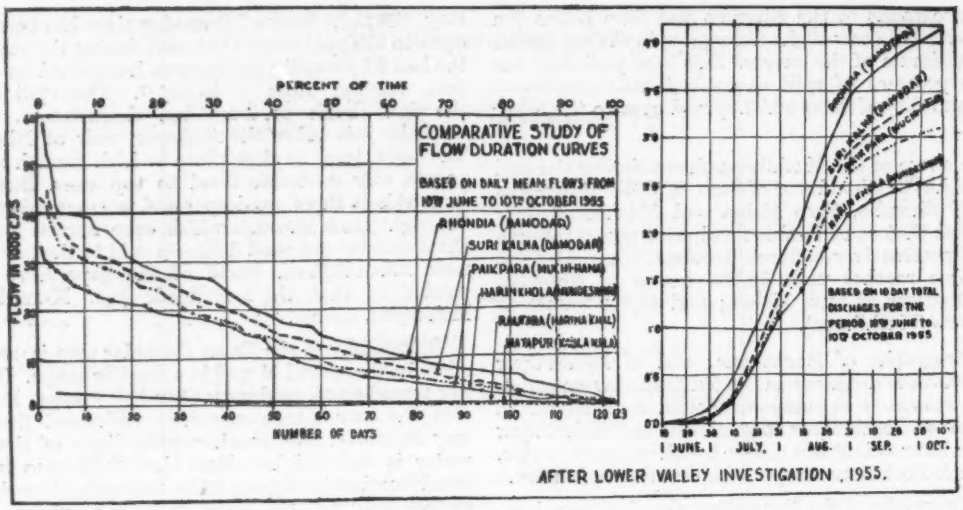

PERCENT OF TIME
COMPARATIVE STUDY OF FLOW DURATION CURVES
BASED ON DAILY MEAN FLOWS FROM 10TH JUNE TO 10TH OCTOBER 1955
RHONDIA (DAMODAR)
SURI KALNA (DAMODAR)
PAIKPARA (MUKUTMANI)
HARIN KHOLA (MAHANADI)
RAJKHOA (HARIYA KHAL)
JHATAPUR (KASILA KHAL)
FLOW IN 1000 C.F.S.
NUMBER OF DAYS
BASED ON 10 DAY TOTAL DISCHARGES FOR THE PERIOD 10TH JUNE TO 10TH OCTOBER 1955
1 JUNE. 1 JULY, 1 AUG. 1 SEP. 1 OCT.
AFTER LOWER VALLEY INVESTIGATION, 1955.

Fig. 36

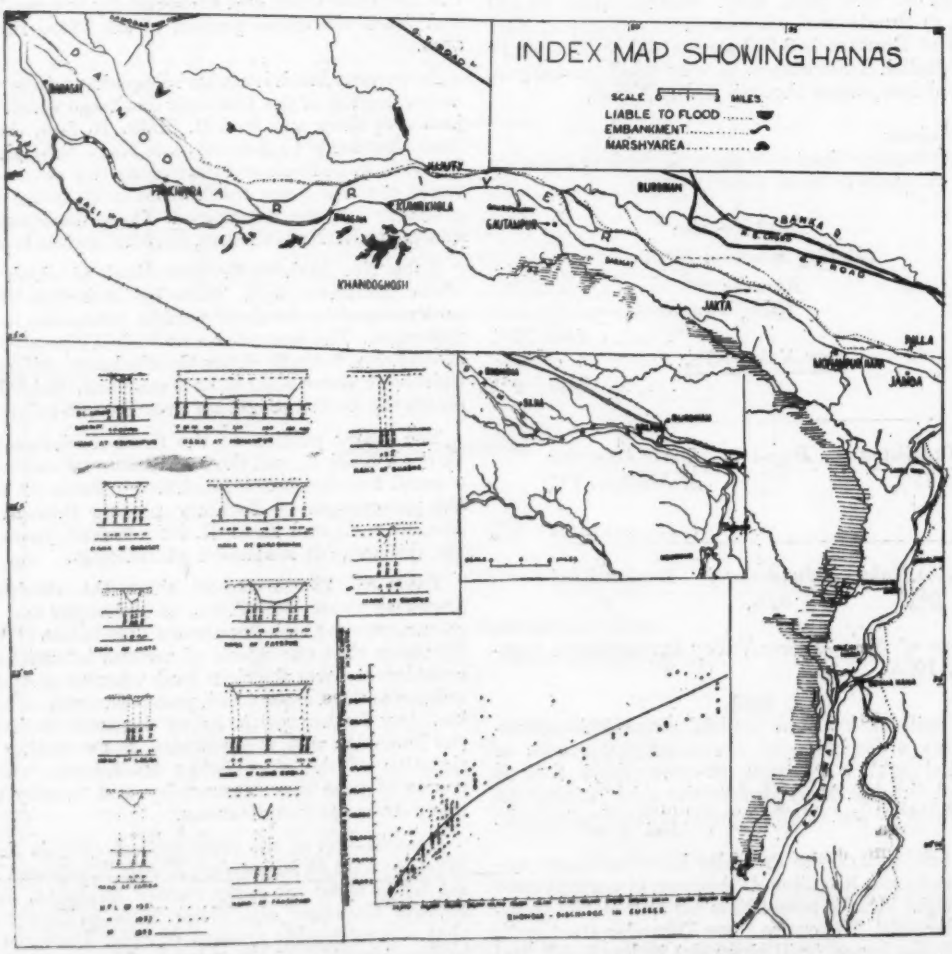


Fig. 37

[Continued on page 42

The Ministry's Report

The Report of the Ministry of Irrigation and Power for the year 1956-57 provides evidence of the wide range and variety of activities that go on under this department.

Among the legislative acts that were enacted during the period under review were: The Inter-State Water Dispute Act, the River Boards Act and the Electricity (Supply) Amendment Act. All these three were important pieces of legislation contributing to a harmonious and rapid development of water and power resources in the country.

The Indo-Pakistan Canal Water Dispute that is still under negotiation with the World Bank was continued throughout the year under review and even now it is hanging fire. It appears it has reached a stage where the issue has to be decided more on a political level rather than on the specialist.

One of the highlights of the year's activities was the cooperation between adjacent states in the matter of control of floods. Ministers of India and Pakistan met at Karachi and New Delhi and surprisingly enough agreed to collaborate in the matter of exchanging flood warnings and rainfall data as and when situation demanded. Similarly, border Himalayan States such as Nepal, Bhutan, Sikkim and Tibet have agreed to cooperate with India in the work of investigations and collections of data. As a result a large number of rain gauges, river gauges and wireless stations have been set up. Two dam sites in Nepal have been located and also a reservoir site. Detailed surveys of the Teesta Catchment by West Bengal have been possible. This is a very important development potentially, as through such concrete steps the cooperation between adjacent States on wider canvas becomes possible in the future; centuries-long isolation is put to an end. We hope that slowly and steadily this work of closar collaboration in mutual interest will grow and expand.

Another important project that was taken in hand in the year was to make an overall study of the irrigation potential of various river basins. This covered three distinct stages, such as preliminary basin-wise irrigation-potential reports, collection of hydrological data, and detailed investigations and project reports. This is a most significant development that needs fullest encouragement. Side by side with this, basin-wise data volumes are being compiled.

In addition to studying the irrigation potential, the CW&PC is also making a detailed assessment of waterpower resources of the country. Already the one on Ganga Basin has been published and a study on the Brahmaputra is in progress.

On the power side, similarly, a national load survey has been undertaken and a preliminary survey for the whole country has been completed. It has indicated that the country is fast becoming electricity conscious and the targets fixed in the Second Plan will fall short of demand considerably.

It appears that with years passing inland navigation is gaining in importance. The CW&PC has developed a Master Plan to link the waterways flowing into the Arabian Sea and the Bay of Bengal. To start with, linking of the Narbada with the Ganga and with the Godavari are now under consideration.

While research on irrigation and hydraulics is much ahead in India, that on power is far behind. A committee was set up for the purpose in 1955 and it has submitted its report in the year under review. We hope that active steps to promote work under this head will be taken, to go hand in hand with power development in the country. We are glad that already some positive steps have been taken in this direction.

Another important Committee, that on Rates and Costs, submitted its report in this period and it has now been discussed among senior engineers. Its report makes very important recommendations, which, if acted upon will considerably tone up our construction work and make large savings to the nation.

The Construction Plant and Machinery Committee has, at the same time, examined in detail the question of "makes" to be standardised. This is another aspect of promoting long term economy that brooks no delay.

The questions of Technical Personnel and training of fresh engineering graduates and serving engineers were also considered during the year. While the Committee's report on the first is under consideration, some concrete steps have been taken on the second.

These are just some of the highlights of the activities of the Ministry and of the CW&PC apart from a large number of their other welknown functions. We are glad that although the CW&PC has ceased to undertake any direct constructional activity, it has fanned out in many directions, specially in planning, investigating, designing, research, scrutinising, training, advising and coordinating the ever-expanding activities of the States in the field of irrigation and power. This is as it should be. The holding of Engineers' Seminar and Power Engineers' Conference periodically as forum of exchange of experience and ideas on expert level among the senior-most engineers in the country further help in providing the intellectual outlook and personal acquaintance between engineers of different states and projects as well as those of the Centre and thus create the very necessary cementing force among those who together are harnessing the natural resources of water and power in the entire country.

(*Continued from page* 40)

Drainage Study of Lower Damodar Valley—II

Table. No. 26 to 30 show the discharge during floods (above 50,000 cusecs) at different hanas. This table shows the occurrence of floods of above 50,000 cusecs within the last 5 years. It also depicts that Mohanpur carries the major portion of the discharge relative to all the other hanas. With the increasing intensity of flood discharge Damodar, R. the amount of water which passes through Mohanpur also increases. Then comes Kumirkhola Barasat and Panchpara so far the flood discharge to pass through these hanas, insignificant amount of flood water passes through Jakta Bhasna, Lacra, Krishnapur hanas. Amongst the abovementioned names Lacra and Krishnapur where flood discharge are a very insignificant in most of the floods, the river-bed remains dry.

References

11. Paramanick S. K. and Rao K. N. — Hydro-Metereology of the Damodar Catchment-Memoirs of the Indian Met. Dep. Vol. XXIX, Part VI, 1953.
12. Satakapon, V. .. Report on the Rainfall studies in connection with the unified development of the Damod r River—Mem. Ind. Met. Dep. Vol. XXVII, Part VI, 1949.
13. Foster E. E. .. Rainfall and Runoff (p. 26)).
14. Satakopan and Raman — Evaporation in India calculated from other Metereological factors Scientific notes, Vol. VI.
15. C. B. I. Journal, July, 1948. — Evaporation and Transpiration loss in Damodar catchment.
16. Voorduin .. Preliminary Memorandum on the unified development of the Damodar river syst m.
17. Roy P. C. .. Movement of sand by the floods of the Damodar and Ajoy Rivers.
18. Annual Report of the West Bengal (p. 53-54). — River Research Institute.

NEW COOLING SYSTEM FOR LARGE TURBO-GENERATORS

Metropolitan-Vickers Electrical Export Co. Ltd. has designed, manufactured and tested the world's first large electrical generator with water-cooled windings. This machine is a 30-mW 11.8-kV 3,000-r.p.m. a.c. turbo-generator with a stator winding cooled by circulating water through the conductors, the water being in actual contact with the live copper. By agreement with the Central Electricity Authority, it will be installed in Bold (St. Helens) Power Station, U.K., as the third of four 30-mW sets, two of which having standard air-cooled generators have been in service for some time; apart from the water-cooled windings the designs are identical, the stator conductors fittting into the same size core and slots.

In the new type of stator the water flows from one end to the other through all the conductors in parallel, and tubes of plastics insulating material connect the conductors to header pipes at each end of the machine. The water circuit includes duplicate pumps and coolers, strainer, flow alarm, water temperature indicator, temperature alarm, and conductivity meter ; it is supplied from a tank placed above the machine and provided with a float-level alarm for detecting leaks.

The generator has been subjected to all the standard works tests, including open-circuit and short-circuit characteristics and losses ; distilled cooling water with a conductivity of 2.5 reciprocal megohms per cm.cube was used. During a five-hour temperature test at approximately full rated load of 37.5 mVA, 11.8 kV, zero power factor, the total loss in the water in the plastics tube connections was estimated to be less than 1 kW (or less than 10 kW if Manchester tap water were used). The maximum rise of the distilled water was 2°C, and the copper temperature rise would only exceed this by the water-to-copper surface rise, which is only 0·20°C. With a pressure drop across the winding of 18 lb/sq. in, the power required to pump the water through the complete circuit was 8.8 kW. Finally a three-phase sudden short-circuit test at full voltage and a high-potential test of 24.6 kV for 1 minute between phases and to ground were carried out, again with water flowing through the conductors.

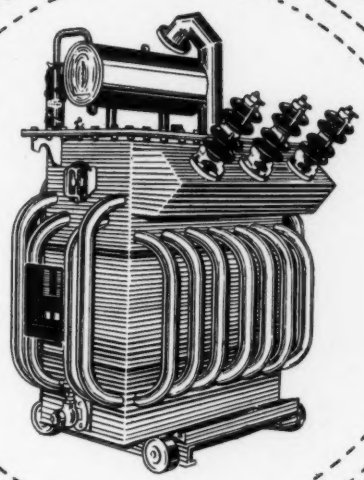
By reducing the size of the stator conductors, and therefore the space required to accommodate them the new cooling system marks a great advance towards reducing the overall size of large a.c. turbo-generators. In the earlier machines of the same rating, the air-cooled conductors have a temperature rise of about 65°C (measured by thermocouple between coils outside the insulation) for a current loading of 1835 A and with cooling air at 35°C, and the corresponding copper temperature is estimated to be about 115°C. The water-cooled conductor on the other hand has carried a current of 1,750 A for 5 hours, after which the copper temperature was 29.2°C, the inlet distilled water temperature being 27°C. It is therefore capable of carrying a very much larger current within the permissible temperature limits for insulation in contact with the copper.

Such developments in cooling systems are essential if turbogenerators exceeding about 200 mW capacity are to be constructed within the present limits of transport in this country, and the information obtained by operating the new generator under ordinary power station conditions will undoubtedly further the present development work on the design of the largest generators likely to be required.

TRANSFORMERS

A LARGE TRANSFORMER FOR YOUR FACTORY

OR A SMALL ONE FOR YOUR WORKSHOP



Whatever the need may be—a small transformer for your residential locality, or a large one for your plant--- from 15 KVA to 2000 KVA --- Kirloskar Electric Co. can supply it.

GPKT-1

Manufactured by **KIRLOSKAR ELECTRIC CO., LTD., BANGALORE-3.**

SOUTH INDIAS' LARGEST MAKERS OF TRANSFORMERS AND ELECTRIC MOTORS.

SOLE AGENTS **PARRY & CO. LIMITED**

MADRAS P. O. Box No. 12
BOMBAY P. O. Box No. 506
CALCUTTA P.O. Box No. 208
NEW DELHI P.O. Box No. 172

Printed and published by P. K. Menon from Inland Printing Works, 60-3 Dharamtala Street, Calcutta-13
Editorial & Managerial Office : 6/2 Madan Street, Calcutta 13

Regd. No. C 3873

THE CATERPILLAR D9 GIVES YOU FASTER PUSH-LOADING AND BOOSTS YOUR PROFITS

In all push-loading operations the more push you have the more dirt you get in the bowl. This speeds up loading and gives more production hours with bigger profits.

Construction Engineers and Contractors all over India and the world are finding that the quickest and most efficient push-loading can be done by the "D9"—the biggest and most powerful diesel tractor made by Caterpillar.

Whether 'direct drive' or with 'torque converter' this massive machine is easy to handle and operating costs are surprisingly low.

Keep and stay ahead with **CATERPILLAR***

*Caterpillar and Cat are Registered Trademarks of Caterpillar Tractor Co., U.S.A.

your partner in earthmoving progress.

Backed by first class service and parts supply.

Use your biggest tractor for all push-loading

TRACTORS (INDIA) LTD.
Post Box 323, Calcutta
Post Box 66, Lucknow

LARSEN & TOUBRO LTD.
Post Box 278, Bombay
Post Box 5247, Madras

WILLCOX (BUCKWELL-INDIA) PRIVATE LIMITED
Post Box 289, New Delhi
New Colony, Jaipur

TRACTOR & EQUIPMENT CORPORATION (PRIVATE) LIMITED
P.O. Box 279, New Delhi

711/P/27

V7
5

MAY

5
7

UMI